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ANNUAL REPORT

OF THE

GEOLOGICAL SURVEY

OF

ARKANSAS,

FOR 1888,

IN FOUR VOLUMES.

By John C. Branner, Ph. D.,
State Geologist.

Little Rock:
PRESS PRINTING COMPANY.
1888.

ANNUAL REPORT, GEOLOGICAL SURVEY OF ARKANSAS.

1888.

VOL. III.

THE GEOLOGY OF THE COAL REGIONS; A PRELIMINARY REPORT UPON A PORTION OF THE COAL REGIONS OF ARKANSAS.

By ARTHUR WINSLOW, Assistant Geologist in Charge.

Table of Contents.

PREFACE.

The annual report for 1888 was originally planned upon the supposition that the four volumes would be published without serious delays. Delays, however, have occurred, and, in the meantime, the work of the Survey in the coal regions has been continued until it is nearing its completion. Instead, therefore, of publishing three or four fragmentary reports, as they would necessarily have to be, it seems to be to the interest and advantage of all concerned to embody the results of the work on the coal regions in a single volume, publishing now only this brief preliminary report upon a portion of the region, for the purpose of making known with as little delay as possible a few of the more important facts concerning our coal. Such an arrangement saves the labor of preparing and editing separate reports, the expense of so many separate volumes and maps, and will, in the end, render the report itself more valuable and more convenient to those who need to consult it.

Detailed topographic and geologic maps upon a scale of a mile to the inch have been made of the area here briefly discussed, but inasmuch as these maps must accompany the final report, it is thought best not to go to the expense of engraving them for the present one. The skeleton map published herewith, will, it is hoped, answer present purposes. In the meanwhile the complete maps may be consulted at the office of the Survey.

The area treated of in this report is not the entire coal area of the State, but it is as much of it as the Geological Survey had time to examine in detail from the time the work began in the coal regions in November, 1887, to the end of 1888.

The investigations of our coal geology being unfinished, a report upon it must necessarily be incomplete also, and there-

fore more or less unsatisfactory. The necessity of postponing the publication of the principal part of the work, the absence of detailed maps, cross-sections and other illustrations designed to accompany the final volume upon this topic, makes it impossible to show the logical connection between the facts observed and the conclusions reached. These conclusions must therefore for the present be accepted largely upon faith. Only such as have to do with matters of economic importance, and require the earliest possible publication, however, are here presented.

The analyses and laboratory tests made by the Survey of our coals lend emphasis to the fact that the indiscriminate use of Arkansas coals, regardless of their composition or physical properties, can result in no good to our coal industry. As is shown by the table of analyses, our coals vary widely in character, and it sometimes happens that a coal remarkably well adapted to one purpose is but ill fitted for another. If these points of difference were properly emphasized in the trade, and if coals were put upon the market and employed for specific uses, such discrimination would greatly benefit both producers and consumers.

With a view to increasing the demand for our semi-anthracite and semi-bituminous coals, attention has been given to the subject of the preparation of soft anthracites and semi-bituminous coals for market, and especially of those used for domestic purposes. The crushing and screening of our friable coals with the machinery used in the preparation of hard anthracites for the market is out of the question, for, by these methods, such an amount of slack coal or waste would be produced as would render the business unprofitable, and, therefore, impossible. Pains has therefore been taken to find the machinery and methods best adapted to the preparation of our Arkansas coals. The results are briefly given in the two papers appended to this report, which, it is hoped, will suggest to our coal producers the simplest and most satisfactory methods of preparing coals for the market. The paper upon the preparation of the semi-anthracites of Bernice, Pa., has been kindly

prepared by Mr. Clarence R. Claghorn, late engineer in charge of the Bernice mines, now of Birmingham, Ala., whose experience in the preparation of coals of this class renders his opinions of great value. In Appendix B is shown a form of screen which seems to be the one best adapted to our soft and friable coals.

Should our coals be assorted and marketed in sizes as the anthracites are, however perfect our appliances may be, the proportion of slack or coal waste must necessarily be increased, and the utilization of the slack then becomes a matter of importance. A chapter of the present report is devoted to this subject, and in it suggestions are offered as to the methods by which loss may be avoided.

The work of this Survey in the coal regions has been carried on entirely under the able supervision of Mr. Arthur Winslow, the author of the report, and the benefits which the development of our coal industry must bring to the State must be credited largely to his skill and ability as a geologist and mining engineer.

Mr. Gilbert D. Harris, as an assistant, has independently examined and mapped an area of over 400 square miles, chiefly in Pope county, and the results embodied in this report concerning this area, are almost entirely the product of his labors. Mr. H. E. Williams and Mr. A. G. Taff, students of the Arkansas Industrial University, as aids, have done a large amount of topographic work in Sebastian, Scott, Franklin, Logan and Johnson counties. The zeal and energy with which these young men have prosecuted their work cannot be too highly commended. Though their share in the results and the quality of their work cannot be expressed here, it will speak for itself in the final report.

To the citizens of the State acknowledgment is due for the general hospitality which they have extended to members of the Survey and for the ready assistance which they have given in the prosecution of the work. The number is too great for it to be possible to make individual mention here. The courtesy of each one is, however, none the less appre-

ciated; and, if, on occasions, it has seemed as if members of the Survey were not willing to reciprocate by imparting information concerning the results of the work, it has been only because of the restrictions placed on them by their duties to others as well as by the law.

The existence in our State of a vast body of coal of unusual excellence, and comprising, as it does, varieties that make it available for a wide range of uses, is of an importance that can scarcely be overestimated. The cheapness and excellence of this fuel, now that it is in a good way to become known, will doubtless enlarge its markets considerably, and will invite the establishment in our midst of many and important industries, while the values of all our other economic products are greatly enhanced by their proximity to an inexhaustible supply of coal.

JOHN C. BRANNER,
State Geologist.

A PRELIMINARY REPORT

ON A

PORTION OF THE COAL REGIONS OF ARKANSAS.

BY ARTHUR WINSLOW, ASSISTANT GEOLOGIST IN CHARGE.

INTRODUCTION.

The conception essential for the understanding of the geology of the coal regions of Arkansas is of stratigraphy or the laws of arrangement of the layers of the rocks of a country.

The superposition of beds, of sandstone, of shale, of limestone, and of coal, one upon the other, and the horizontal continuity of these rocks over great distances, cannot have escaped the notice of even the most careless observer. The great beds of mountain capping sandstones so prominently exhibited in the escarpments of Petit Jean mountains, the hills at Ozark, at Van Buren, near Enterprise in Sebastian county, and at innumerable other places are but remnants of such layers once connected in great overspreading sheets. These layers were formed under different conditions: the limestones in ocean depths, the sandstones in the more rapid currents of shallower waters, the shales and coals probably in the shallow and well-nigh stagnant waters of endless lagoons and marshes, rich in a tropical vegetation. All these beds, however, were deposits in the form of layers, or great sheets, one upon the other like the leaves of a book, and are known, in geology, under the familiar term "strata." In Fig. 1 of the accompanying page plate I, is shown an ideal arrangement of the strata in section as they would have appeared at the time of their deposition if cleft vertically open.

PLATE I.

Geological Survey of Arkansas — *Annual Report 1888 Vol. III*

Fig 1

Ideal Diagram showing the position of the strata at the time of deposition:

Fig 2

The same, subsequent to upheaval and prior to denudation

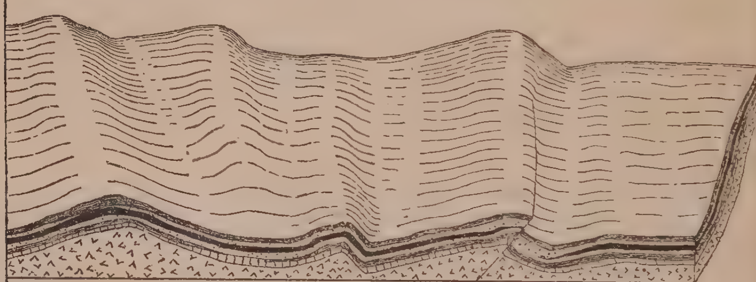
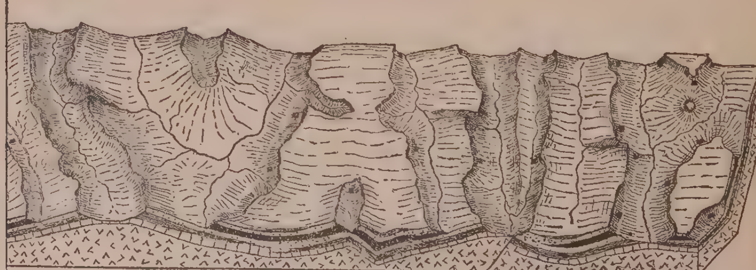


Fig 3

The same, subsequent to the action of denudation



Another equally apparent fact, however, is that while the various rocks are arranged in successive layers or strata, these layers are often not horizontal but are tilted at an angle with the horizon, sometimes slight and sometimes nearly vertical. Such disturbance is beautifully exhibited along the crest line of Devil's Backbone ridge, south of Greenwood in Sebastian county. This flexing of the rocks leads one to a consideration of the subject of geologic dynamics. The tilted position of the strata is not the original one, but has resulted from a bending, crumpling and upheaval of the once horizontal beds, due in some cases to a shrinkage of the earth's crust, in others to local seismic or volcanic action. In Fig. 2, of Plate I, an attempt is made to illustrate these changes from the horizontal to the bent and tilted condition. How much useless and costly boring and drilling after coal, iron, oil, gas, salt, or what not, would be saved if the true significance of this tilting of the rocks were generally appreciated. By reason of such disturbances, strata, which may be many hundreds of feet deep at one place, present their edges at the surface perhaps only a few miles distant. By a study of the succession of these protruding edges, or outcrops, as they are technically called, it is often possible with a few days' work to construct nearly as satisfactory a rock column as could be obtained from an expensive drill hole.*

In Fig. 2 the strata are seen to be practically continuous, whereas, on the ground, nothing is so apparent as the abrupt termination of these layers of rock, where they jut out from mountain sides or protrude from the ground. It is often difficult for the uninitiated to believe that the continuation of such a stratum exposed at one locality is to be found in some hillside miles distant, and that the connection was once an actual and material fact. This is nevertheless true. By the slow but sure action of what are called the forces of degradation, or the continuous effects of air, rain, snow, ice and running water of

*The writer does not mean to deny the almost indispensable usefulness of the drill for many purposes of prospecting. He does mean to affirm, however, that there is probably more waste of money from its ignorant use in many a State than would equip and maintain a complete geological corps.

brooks and rivers, these great gaps have been carved out. The friable and the hard massive strata are first broken into blocks, then softened until they disintegrate into their ultimate grains and are washed away. And this has been going on for countless ages and is now in progress before our very eyes, so that of some great sheets of rock only the smallest fragments are left. In Fig. 3 this result is shown clearly by a varied profile of a succession of mountains and valleys of a shape and structure common in Arkansas at the present day. The identification of these various rock layers from place to place, or, technically expressed, the unravelling of the stratigraphy of a region, is one of the chief functions of a geological survey; to define the distribution of these layers is one of its chief objects, and without a knowledge of this stratigraphy economic work cannot be intelligently undertaken or successfully carried on.

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CHAPTER I.

PHYSIOGRAPHY AND GENERAL GEOLOGY.

Previous Work.—As far as concerns any of its structural or stratigraphic details, the geology of Western Arkansas was a veritable *terra incognita* at the time when the work of the Geological Survey was begun in the coal regions. Nutall, Shumard, Marcou, and others in a private capacity, had traveled through this portion of the State during the first half of the century, and their notes on the geology of the country are to be found in various official publications or in scientific journals. These notices, however, are all very meagre, and consist either of mere local descriptions or of very broad generalizations. Even Owen's work lays no claim to being anything more than a geological reconnoissance, and no map showing even the approximate distribution of the geologic formations accompanies his reports; no attempt is made to delineate geologic structure, while the positions of anticlines and synclines are referred to only in the most disconnected and incidental manner, along with the description of counties; the correlations of the coal beds are made from very general data. In short, none of this work accomplished even approximately the results which nowadays are demanded of a geological survey.

The area here specially treated of represents only a portion of the coal region of the State. Reference to the small map accompanying this report will show that this area is an irregular one covering nearly 2000 square miles. It extends east and west along the Arkansas river from the Indian Territory line to Dardanelle, a distance of about 75 miles. Over the western portion it stretches southwards as far as the Poteau mountains; but the eastern half does not extend in any place more than

fifteen miles laterally from the main drainage channel. This area was outlined so as to include those districts which, when the work was begun, were believed to be of prominent importance as coal producing sections. A knowledge of the geology of this area would also furnish a key to and was necessary for the determination of the coal distribution over adjacent areas. The boundaries were arbitrarily fixed along range and township lines and they include townships 4 to 10 north of the base line, and ranges 20 to 32 west of the fifth principal meridian.

The Physiography of this region, in its general characteristics, is similar throughout, and this physiography may be considered as typical of the valley of the Arkansas river in Western Arkansas; of that area which stretches from the Boston mountain system on the north, to the Poteau and Petit Jean ranges on the south, and from which all waters flow into the Arkansas river. Unlike the eastern part of the State, and contrary, perhaps, to the general conception, the surface features are both varied and bold. The peaks of granitic or the bald summits of glaciated areas are, of course, wanting. The topography is essentially one of stratified non-metamorphic rocks. Sharp crested, parallel ridges, long and wall like, and plateaus, terminated by abrupt declivities, abound, with their correlatives, trough shaped valleys or steep sided rocky gorges. The mountains are generally great masses of strata piled horizontally upon each other; remnants left by erosion of sheets formerly overspreading wide areas, of which remnants the hard, resisting layers stand out in concentric escarpments. Widely varied, yet always expressive of geologic structure, topography here becomes of intense interest and of first value with relation to the geology. In fact, it may be said of this country, as has been said of the Appalachian region of Pennsylvania, that "we recognize a country where, from the comparative deficiency of fossils" * * * "the science of geology transforms itself into the science of topography."*

*J. P. Lesley, Manual of Coal and Its Topography, p. 122.

The ranges of level are not very great. The altitude of the river bottoms varies from about 320 feet near Dardanelle to about 430 feet at Fort Smith, and the mountains in the southern part of Sebastian county (the highest within the area described) reach an altitude of 2600 feet.

The whole area under discussion may, in a broad sense, be considered part of one great valley, that is, as constituting part of a single drainage basin, bounded on the north and south by mountain ranges. But, in a more restricted sense, innumerable minor valleys are to be recognized in those depressions which intervene between and are complementary to all the various mountains, ridges, and other minor elevations. With reference to geologic structure these valleys are monoclinal or longitudinal, anticlinal, synclinal, or they are valleys in horizontal strata. With reference to surface details, to soil, to vegetation, each and all of these various classes may be, in whole, or in part, either rugged, undulating, or flat, may be wet, alluvial bottoms or dry loamy or rocky uplands, may be densely covered with forest growth, or may be bald, almost treeless prairies.

The drainage of this country, like the features of relief, is expressive of the geology, though to a less degree. It is indicated in the course, the declivity, the position of the channel, the area of the flood plain and in the nature of the water of a stream. The drainage of Western Arkansas is typically that of an area of non-metamorphosed stratified rocks. The Arkansas river is the only stream of the region which can be considered navigable. Its tributaries are all of small size, none having a drainage area much exceeding 500 square miles. The Poteau river, which might be considered an exception, having a drainage area of nearly 1500 square miles, is not properly within the State, its mouth being in the Indian Territory, while only its upper portion and some small tributaries are in Arkansas. The larger creeks which flow into the river are, during wet weather, large and bold streams of turbid water, often unfordable for days. Owing largely, however, to the mountainous and hilly character of much of this drainage area, the

water flows off very rapidly and these streams are generally easily crossed on foot at shoal places; while during the prolonged drought of late summer and autumn the flow of water, in even the larger creeks, ceases entirely, and occasional stagnant and muddy pools in the hollows of the channels are all that remains of what, after the last shower, was, perhaps, a raging torrent.

The lithology of the coal regions is monotonous in the extreme. Sandstones and shales make up almost the entire list of rocks. With the shales is associated the coal, while some thin beds of iron carbonate concretions also break the uniformity. An occasional layer of calcareous shale is also seen, but nothing that deserves the distinction of the term limestone bed is found within the area here discussed. *The shales* form a hard and compact rock where not exposed to the weather, but after such exposure they become exceedingly soft and fissile. They are either argillaceous or arenaceous; sometimes light gray in color, sometimes dark gray, or even black and bituminous. They weather to a gray, yellow, or reddish color, and, when ultimately decomposed, form a stiff grayish or yellowish clay. They are often micaceous. After slight weathering and partial decomposition the bedding planes become quite prominent, and there is often a distinct cleavage along these planes. *The sandstones* may be either massive, thinly bedded, flaggy, or even shaly. They are generally highly siliceous and of a light gray color. They sometimes exhibit false bedding, and also often have developed in them a peculiar, crumpled cleavage. This, together with the homogeneous nature of the rock as a whole, generally obscures the stratification marks. A prismatic jointage frequently gives to the surface of the beds a tesselated appearance.

No attempt will be made here to define the stratigraphic positions of all the various sandstones and shales, except in so far as is done in the provisional discussion of the relations of the different coal horizons. More than ten different groups of sandstone strata have been identified, separated by hundreds of feet of shale, the whole making a most imposing column.

Their distribution is an intricate problem to unravel, and involves the consideration of the effect of a complex system of rock flexures. And it is further complicated by the fact that these different stratigraphic groups are not persistent. In places a ridge-forming sandstone becomes so attenuated as to have no topographic prominence; a sandstone bed, heavy and massive in one place, may, within a few miles, become flaggy or shaly. On account of the paucity of fossil remains paleontology offers no aid in the identification of the various beds. The only solution is by a minute study of the topography and lithology. No attempt will be made to correlate these subdivisions of the carboniferous with those of other States. Such topics are properly withheld for discussion in the final report upon the coal regions of the State.

The structural geology of this region, so far as relates to rock flexing, is one of the most important, and offers the most interesting questions for detailed study, both with regard to the dynamic of the origin of the disturbances, and also to the resultant structural features. Indeed, it is of the nature of an interesting surprise to find here, west of the Mississippi river, and apparently beyond the influence of the Appalachian upheaval, a repetition of those folds and crust contortions which were so enthusiastically studied in the East by the older geologists. A discussion cannot be entered into here, nor can any satisfactory general description be given. The axial line of maximum disturbance lies many miles south of the area here described, while a few miles north of this area the strata lie in a nearly flat and comparatively undisturbed position. Between these extremes, from north to south, there is a progressive increase of rock flexing, and within a distance of twenty miles south of the Arkansas river the anticlinal and synclinal folds are developed in full force.

CHAPTER II.

THE DISTRIBUTION OF THE COAL.

To establish the relations of the coals at the various localities examined, to define the limits and to fix the area of the different coal beds thus recognized involves the correlation of the principal stratigraphic divisions of the area under discussion. Such a correlation is represented on the small map accompanying this report. The results there embodied are, however, of variable degrees of reliability. The difficulties in the way of identification have already been referred to on page —. The conclusions offered are in part self-evident and necessary from the observed facts, while elsewhere they can lay claim to being only such as the facts suggest. The relations between these facts and conclusions cannot be displayed here. Such demonstration is necessarily reserved for the final report. And, in the meantime, this correlation is in part hypothetical; it is provisional, and subject to such modifications as the extension of the work in the coal regions may warrant.

The coal beds of Western Arkansas are invariably associated with dark fissile shale. This shale has often an uninterrupted thickness of over 200 feet. The coal seems always to occupy a position near the base of the shale, and to be separated generally by only a short distance from a thick underlying bed of sandstone. Hence to define the basal limits of this shale defines very nearly the position of the coal beds The areas variously shaded on the accompanying map show the general distribution of the argillaceous or shaly, and of the arenaceous divisions which are provisionally recognized. Of the former, or argillaceous divisions, two may be considerd as distinctively coal bearing. First, *a western and upper division* in which are all the various coal openings which have been examined in Sebastian and Scott counties, the western

part of Logan county, and in that part of Franklin county which lies south of the Arkansas river; also the small coal basin lying in the central part of Johnson and Franklin counties, containing the Philpott coal mine, is inferred to be of this division. Second, *an eastern and lower division* in which are the various coal mines in the vicinity of Coal Hill and Spadra and also the Ouita and Shinn coal mines near Russellville in Pope county. These two divisions are separated by a succession of shales and sandstones which though variable in magnitude have an aggregate thickness of not less than 500 feet.

The Western and Upper Coal Bearing Division

Is represented by the lightest shade on the map and is numbered 1. Vertically it is taken to include a succession of sandstones and shales which overlie a persistent bed of sandstone, which latter is thus recognized as the bottom rock, or floor. In the southern portion of Sebastian county and in adjoining parts of Scott county this division includes the strata of White Oak, Poteau and Sugar Loaf mountains, and here the collective thickness must be close on to 3000 feet. In no other place is, however, such a great thickness represented.

As many as three distinct coal beds are recognized here, but they are not all persistent. Of these the lowest bed is the most important and the most extensive. It occurs in a thick bed of shale at the bottom of this division and often lies close to the bottom rock. The sinuous line which defines the limits of the division on the map, therefore, very nearly represents the outcrop line of this coal bed.

In Scott county and in the southern part of Sebastian county this coal is opened in succession from east to west at Harrison's pits, at Bagwell's pits, at Gibson's pits, at Claiborne's pit, at Chasteen's pit and at Gwyn's drift, all of which are located and named on the accompanying map. These openings have been made along the outcrop of the coal bed at irregular intervals and the coal dips from them southward and passes under the White Oak and Poteau mountains. The bed varies

considerably in thickness and character here as the following list of sections shows:

At Harrison's coal pit is:

Coal .... 20 inches.

It is doubtful whether this represents the entire thickness of the bed here. Comparison with the following sections would lead one to infer that this might be only one bench and that careful prospecting would reveal other benches closely underlying or overlying this one.

At Bagwell's coal pit is:

Coal .... 3 feet.

This coal may also represent only a single bench as with the preceding.

At Gibson's coal pits the following section was measured:

	Feet.	Inches.
Coal	1	
Shale	1	
Coal	1	3
Shale	5	
Coal	1	6

At Claiborne's coal pit:

	Feet.	Inches.
Coal		10
Shale		4
Coal, with slate		8
Coal	1	7
Shale	2	6
Coal	2	4
Shale	2	0
Coal		4 to 12
Shale	8	
Coal		3

At Chasteen's coal pit:

	Feet.	Inches.
Coal	1	
Shale		3
Coal		6
Shale		3
Coal	2	1

At Gwyn's coal draft:

	Feet.	Inches.
Coal	4	
Shale		8-10
Coal		10-12

Another bench is said to have been struck in the creek bed beneath this, but nothing authentic could be learned concerning it.

A comparison of these sections would lead to the conclusion that proceeding eastward from Gwyn's drift the coal bed is divided by shale into numerous benches and that these benches become so attenuated that it could not be profitably mined on any large scale. To what extent this may be the case cannot, however, be predicted until the bed has been more fully proved.

West of Gwyn's drift the coal dips beneath the surface and must pass under Hartford and underlie all of the surrounding country.

The Gwyn opening is in the axis of a great anticlinal fold, and the outcrop line, which we have traced to this point from the east, there bends abruptly around in a loop and continues in a northeastward course to and beyond Huntington. Within this distance the coal has been opened on at West's pit, on Wininger's land, on the east bank of James Fork, at Frazier's pit, at Patterson's pits and at the Huntington coal mines.

At West's pit the coal is reported to be about 8 feet thick, and is divided near the middle by a few inches of shale. Only the upper bench has been worked, however, and there is some doubt in the writer's mind concerning the existence of the lower bench.

At Wininger's the coal is reported to be $3\frac{1}{2}$ feet thick. The dip of the coal at these points is northwestwards, and it passes down and under Sugar Loaf mountain.

At Frazier's and Patterson's pits the coal bed has approximately the same section as at the Huntington mines, where it is as follows:

	Feet.	Inches.
Coal	4	
Shale		10-12
Coal		6- 8
Shale		4- 6
Coal	2	

The Huntington mines are located near the eastern end of a narrow coal basin, and the openings last enumerated are along the southern outcrop of the coal of this basin.

A number of small openings have been made on the opposite side of the basin along the northern outcrop. The Spessard and Kersh drifts are such, and the coal as exposed at these openings has about the same thickness and is divided into the same number of benches as at the Huntington mine.

From the Kersh drift the border line of this upper coal division is shown on the map to bend around to the north and to continue in that direction for some six miles. The coal outcrop must be within a short distance of that line, and westwards the bed must sink gradually beneath the surface and underlie the whole area shown on the map, getting deeper and deeper as it approaches the Indian Territory line. This coal has been opened on near the eastern limiting line at the Pulliam pit, in Powell's well and at Martin's pit. At the Pulliam pit the bed is 3 feet 2 inches thick. It is claimed that an underlying bench exists here and that it is exposed in the bed of the adjoining creek at low water. It is difficult to say whether this is another bench of coal or merely the same bench brought to a lower level by a slight increase of dip. From comparison with other records in this neighborhood the inference of a second and lower bench is, however, warrantable.

In Powell's well the following section is reported:

	Feet.	Inches.
Coal	4	
Shale	3	6
Coal (not dug through)	2	2

At Martin's pit the coal is reported to be four feet thick.

The northward course of the division border line continues for some four miles north of Martin's pit. It then makes another abrupt bend and continues in a general course a little north of east for over twenty miles to the limits of the map. This line represents the southern outcrop of the northward dipping and lowest stratum of this division, and the outcrop of the coal is believed to be closely associated with it. Only at one point, within this distance, however, has its exact location been indisputably proved, namely at Page's pit close to Vache Grasse creek. The coal was first opened on here as late as the Autumn of 1888, and it was a discovery of peculiar gratification to the writer inasmuch as the coal had already been assigned this position by the Survey. About two feet of coal was dug through in this pit when inflowing water stopped further digging, and the bottom of the bed was not reached.

Langston's coal pit, on Big creek, is near the supposed outcrop line of this coal, but other considerations lead to the conclusion that the coal struck here belongs to an overlying bed and that the horizon of the bottom bed is in the valley beyond the low ridge immediately south of this pit.

The border line of the division, which separates it from the elongated barren area, extending into the State from the Indian Territory between Hackett City and Jenny Lind, defines approximately the outcrop line of a coal bed which is at the same horizon and is presumably the same coal as that thus far described. On the south side of this barren area the coal is opened, on a south dip, at Hackett City, at Sewell's pits, at Greenwood and at McConnel's shaft.

At Hackett City the coal is about 3 feet thick without any parting. At Sewell's pits nothing reliable was learned concerning the thickness, and the opening consists merely of two shallow trial pits.

At the Greenwood shaft the following section is exposed:

	Feet.	Inches.
Coal	2	8
Shale with a little coal		4 to 14
Coal	3	3

At McConnel's shaft the section is:

	Feet.	Inches.
Black shale with thin coal seams	2	6
Coal		4
Shale		1
Coal	2	5

About half a mile east of McConnel's shaft the coal has been dug in a pit, but thence eastwards, around the point of the barren area, and westwards to beyond Oak Valley no coal has been struck adjacent to this border line. Within two miles west of Oak Valley, however, several wells have penetrated the coal, and beyond these it has been successively worked, on the north dip, at Carnall's drift, Watt's slope, Breen's shaft, Petty's slope, Spark's slope and Bocquin and Reutzel shaft.

At Carnall's drift the following section was measured:

	Feet.	Inches.
Coal	2	6
Shale parting		2
Coal	1	4

At Watt's slope the coal varies in thickness from 3 feet 6 inches to 4 feet 2 inches with a shale parting about midway.

At Breen's pits the coal is reported to be a little over 4 feet thick.

At Petty's slope the following section was measured:

	Feet.	Inches.
Coal	2	6
Shale		2
Coal	2	6

At the Bocquin and Reutzel shafts it is about 5 feet thick and is divided into two benches by a parting of shale 2 or 3 inches thick.

At Buzan's shaft the following section was reported by the owner of the land:

	Feet.	Inches.
Coal	4	4
Shale	5-6	
Coal, and shale intermixed	4	

The coal bed defined by these openings dips northwards under Long prairie and the valley of Vache Grasse creek and is considered to underlie the upland country beyond this to the north. Coal has been struck in a drill hole about a mile south of Enterprise, close to the Frisco railway, but is reported by the Kansas and Texas Coal Company to be only 18 inches thick.

The deep drill hole of the Fort Smith Gas and Power Company, in Massard prairie, in the northeast corner of township 7 north, range 32 west, did not pass through any coal, according to the statement of the company. The most probable explanation of this is that the gentle anticlinal flexure, the axis of which passes near this hole, has brought the coal to the surface and it crops out immediately north of the well at Breen's pit, is struck in Quanti's and McNally's shafts, and in wells east of the last. The coal at McNally's is reported to be 24 inches thick, divided by a half inch seam of slate, 20 inches of coal above the parting, and 4 inches beneath, the latter thickening, however, to 14 inches northwards.

This bed of coal undoubtedly passes under the country to the north of these openings, and the bed struck in the Fort Smith gas well at a depth of about 550 feet is inferred to be the same. This coal, or its stratigraphic equivalent, must extend under the Arkansas river and under the country north of Van Buren to and beyond the limits of the map. Where it again reaches the surface by reason of the general uplift along the Boston mountains will be demonstrated by the next season's field work.

The broad belt of this upper division which extends eastward from Big creek was referred to on page 11, in describing its southern border line. Its northern border is boldly defined by the protruding sandstone floor which rises in a massive ridge to the north. Close on to this bottom rock coal is again struck, but at wide intervals. At Vesta, about six miles north of Charleston, it crops out and is dug through in wells.

Between this northern and the southern border line coal has been opened on at a great number of places; but all this coal is considered to belong to overlying beds. The prospects are, therefore, favorable for the discovery of another deeper lying coal bed within this area. Its probable depth at various localities cannot be stated here, but it will be shown on the maps and cross sections accompanying the final report. Its thickness cannot be predicted until some judiciously located provings furnish the facts necessary for the deduction of general rules.

The Philpott coal area in Johnson and Franklin counties has already been mentioned as presumably part of this upper division. At the Philpott mines the coal lies in a shallow and elongated basin, associated with fissile shales and flaggy sandstones, and is underlain by a bottom rock of thickly bedded sandstone of which the basset edges form an encircling ridge. The coal is not far from the bottom rock and is opened at several places along both the north and south sides of the basin. Along the southern side the coal dips to the north and has been opened at Hunt's shaft, Philpott's shaft, and Moomaw's pit. At these openings the coal is from 18 to 24 inches thick. Along the northern edge of the basin the coal has been dug, on the south dip, at Pyon's and Quall's pits, where it is reported to be of the same thickness.

The upper coal beds of the western or upper coal division have their distribution by no means so well defined as has the lowest bed thus far described. The persistent and thick sandstone stratum underlying the latter is often of topographic prominence and fixes boldly the approximate limits of this coal. The overlying beds lie in detached areas in the general basin, and in the mountains and isolated hills where the remnants of the upper strata are represented. Hence, the correlation of these upper coals is more difficult. The many gaps preclude the possibility of actually tracing the coal from place to place, and the best means for deducing their relations is with reference to the underlying coal or to its bottom rock. The distribution of these beds will not be described in this re-

port, nor can it be shown on the small accompanying map; but on the large maps, designed for the final report, all such matter will have place.

In the Poteau mountains, in the southern part of Sebastian county, such a coal bed exists at an elevation of about 500 feet above the adjoining valley, and must extend through the mountains in a sheet, bent into a slight synclinal fold. It is opened at a point on the north slope of the mountain, about three miles southeast from Hartford, known as Noblet's pit. The following section was measured here:

	Inches.
Coal	4
Soft shale	5
Coal	3
Shale	4
Coal	5
Shale	4
Coal	6

Further alternations of shale and coal are reported to underlie this, the whole having an aggregate thickness of about seven feet.

East of this point the same coal bed crops out at various places in the mountains but as it has not been worked, no further records of its thickness were obtained.

In Leatherwood's well, near the Indian Territory line, west of Hartford, coal is reported to have been struck and is thought to be several feet thick. This coal would belong among the lower benches of the Poteau and Sugar Loaf mountains and would underlie the coal last described.

On Sugar Loaf mountain, coal, which is probably the equivalent of the Noblet coal, is known to exist at several places. It crops out in the road near the summit of the gap north of Hartford. It has been dug in a ravine about a mile east of this gap, and the following section was measured from an imperfect exposure:

	Inches.
Coal	10
Shale	10
Coal	6

More coal may underlie this.

There are further rumors of its occurrence at points in the mountain east of this opening. North of Sugar Loaf mountain and west of Sugar Loaf Post-office coal is reported to have been struck in Glidewell's well, about four feet thick. This is evidently at or near the horizon of the coal struck in Leatherwood's well and the bed thus underlies all of the country between these two points.

On Griffith's hill, southeast of Hackett City, coal is reported to have been struck in several wells. In distribution it must be confined to this and associated elevations. In Wigginton's well the coal is said to be four feet thick. In Diffie's well alternations of shale and coal are reported to have been penetrated for a thickness of 15 feet.

Over that portion of this division which lies north of Jenny Lind and west of Big creek, coal of overlying beds has been struck at comparatively few places.

In the uplands immediately north of Jenny Lind, about four feet of coal is reported to have been struck in Buckley's well, dug over thirty years ago.

At Central a bed about 20 inches thick is worked in open pits.

In Fort Smith coal is reported to have been struck in Dudley's well at a depth of about 90 feet and is said to be four feet thick. An upper coal bed is also reported to have been passed through in the gas well in the city at a depth of about 160 feet, and this would be at the same geologic horizon as the coal reported in the Dudley well.

Herman's coal pits, two miles northeast of Fort Smith, are said to have been opened in coal about 2 feet thick, and the same bed was struck in the Wilson gin well. This must overlie the Fort Smith coal last described.

In Van Buren an overlying coal bed has been struck in several places. In Hayman's well it is reported to be 14 inches thick.

In Hendrick's pit, about three miles northeast from Van Buren, about 2 feet of coal was dug through, and, on drilling deeper, some three feet more of coal is thought to have been passed through, separated from the upper bench by about 5 feet of shale.

South of Alma the coal dug at Graves' drift, 18 inches thick, and at the Sullivant pits, 13 inches thick, apparently both belonging to the same upper bed. It is hence to be inferred that deep drilling in this vicinity may reveal a deeper-seated coal bed.

With the deepening of the basin east of Greenwood the upper strata of this division are better developed and at least two upper coal beds can be recognized. The lower one of these is represented at the Langston coal pit, where the bed is variously reported to be 18 inches and between 2 and 3 feet thick. The upper one is represented by the coal struck in Hearn's and other wells and reported to be from 1 foot to over 3 feet in thickness. It is also dug in Bean's pits, where it is about 20 inches thick. Thence northwards, along Big creek, this upper bed has been opened at numerous places. At Roose's pit it is about 20 inches thick, at Fletcher's between 18 and 24 inches. The northern outcrop line is easily traced from the last mentioned pit, eastward to Charleston, past a number of different openings in which the coal is reported to vary from 18 inches to 3 feet in thickness.

At Charleston the bed has been struck in a number of wells in the south edge of the town, and in these the thickness is stated to vary from 18 inches to over 4 feet in Newton's well. It hardly seems probable that the bed attains the latter magnitude, but the report deserves investigation. The coal struck in Brown's wells must belong to a lower lying bed.

Over the prairie country lying east of Charleston, gentle undulations of the strata bring the several coal beds to the surface in a large number of places, where they are worked by

shallow pits. In the southern portion, along Six Mile creek, are the Lambert pit and several others, but the coal is not much over a foot in thickness. In the northern portion are the Holder, Kellum, Cotton and other pits in which the coal is about 18 inches thick. At the Carpenter pit the bed is variously credited with a thickness of from 18 inches to over 3 feet.

Still farther eastward, down Hurricane creek, are few occurrences of coal to beyond the confluence with Six Mile creek. Thence around the northern foot of the two Short mountains, the northern outcrop of a coal bed is distinctly traceable, from Goldsworthy's pit to where it passes beyond the area of the map at Titsworth's pit. This bed, as measured by the Survey at various openings, is about 2 feet in thickness, but it is reported to be three feet and more at other points. It must continue under the Short mountains in a continuous sheet and it crops out again on the south sides of the mountains.

The Eastern and Lower Coal Bearing Division

Is shown on the map by the shade numbered III. It includes a large body of dark fissile shale which, in the vicinity of Coal Hill, is at least 250 feet thick. In the vicinity of Ouita, in Pope county, they are reported by Mr. Harris to be of about the same thickness. Sandstone immediately underlies this shale which, though of variable character, is generally thick and massive and often of topographic prominence.

The coal of this division is near the base of this shale and the underlying sandstone is currently recognized as the "bottom rock." The westward openings are in the vicinity of Coal Hill, in Johnson county. At Stiewel & Company's mine at this place, the bed has approximately the following section:

	Inches.
Coal	21
Shale and coal	4
Coal	25

From here the coal is interpreted to extend under the country to the north.

At the Allister slope of the Ouita Coal Company, two miles west of Coal Hill, the thickness of the coal is about the same. This mine is opened by a slope which enters the coal at the outcrop near the crest of an anticlinal axis. The coal extends farther westwards but sinks deeper and has not been opened upon. A number of drill holes have however demonstrated its presence, and also the continuance of the anticlinal flexure. This is shown by the result of drilling at points marked *a*, *b* and *c* on the map.

At *a* the coal was struck at a depth of 457 feet.

At *b* the coal was struck at a depth of 51 feet.

At *c* a hole was sunk 150 feet through the shale of this division without reaching the coal.

The difference in altitude of the surface at these different holes cannot be more than 30 or 40 feet.

The thickness and character of the coal under the country beyond these provings cannot of course be definitely stated. It is probable that it remains essentially the same under the contiguous area. Farther west the coal opened at Lewis's, near White Oak, about 14 inches thick, and cropping out under the bluffs on the south side of the river in this neighborhood, is apparently at about the same horizon as the Coal Hill coal, and may be the attenuated extension of this bed.

The area included in this division on the map, in the western end of Logan county and adjoining portion of Sebastian county, seems to be almost barren of coal, excepting in the vicinity of Booneville and southwest from that place. At Carlan's slope there are alternations of coal and shale aggregating about 5 feet in thickness.

East of Coal Hill the division classification becomes very difficult, and there is considerable doubt as to the exactness of the interpretations expressed on the map. What seems to be the same coal bed, has been opened at Allen's drift, on Horsehead creek and in Harkreader's well, and, at both of these places the coal is reported to be about 4 feet thick, divided into two benches by a thin shale parting.

Eastwards from Harkreader's the exact line of the coal outcrop cannot be traced. Croppings of coal appear at several places along the border line of this division, as shown on the map, but towards and beyond Spadra creek it becomes very difficult to define even this border line. The various streams flowing from the hilly country on the north meander through this area in very irregular channels and the stratigraphy is hidden by accumulations of gravel and other deposits over the low hills. Further there seems to be here a thinning out of the shales of this division and a partial substitution of heavy sandstone beds. On this interpretation the coal at Mason's is held to be at this horizon. It is 16 inches thick. It overlies the sandstones of the hill to the north and east and is struck in places near the summit of this hill, whence, with a north dip, it passes down under the country to the north. The drill hole sunk by the Clarksville Coal and Iron Company, in section 10 of township 10 north, range 23 west, is reported to have passed through some 6 feet of coal, separated near the middle by about 3 feet of "rock." Thus this would be the same coal bed. The coal would extend westwards with this division and the coal at the Kendall drift would belong at the same horizon, as is shown on the map.

The probable position of the outcrop line along the north side of the river is shown approximately. The coal is opened on at several places near Spadra, with the following section:

	Inches.
Coal	17
Shale	1
Coal	19

The coal has here a slight but persistent northward dip and is considered to extend under the country in that direction, reappearing at Harkreader's, but underlying Clarksville and Big Danger Hill southeast of that place. The broad extent of alluvial bottoms along the north side of the river prevent the tracing of the outcrop east from Spadra, but the distribution of overlying rocks warrants the conclusion that this bed, or its stratigraphic extension, continues in that direction into Pope county, as is represented on the map.

South of the river, between Coal Hill and Spadra, this coal horizon is interpreted to be carried beneath the surface by the gentle anticlinal flexure referred to on page 23. A parallel synclinal flexure to the south brings the coal again to the surface, however, near Prairie View. At the last named place the coal is reported to be about 3 feet thick, but is divided by over a foot of shale. The outcrop line of this bed must continue eastwards in a nearly due east course and the coal exposed in the bed and at the mouth of Shoal creek is undoubtedly the same.

Over the western part of Johnson county and in Pope county the distribution of the shales of this division is clearly shown on the map. The associated coal is proved and worked at only two localities. At the Ouita mines of the Ouita Coal Company the coal is about 30 inches in thickness. It is opened by a slope driven in on the outcrop near the terminus of the coal basin. The coal lies close upon the upper surface of the underlying sandstone. Other openings of minor importance have been made in this bed in the immediate vicinity.

In the small, isolated Shinn coal basin, south of Russellville, two coal beds are recognized, one about 30 feet above the other. The lower, like that at the Ouita mine, rests upon the upper surface of the underlying sandstone. It is about 18 inches thick and is said to strongly resemble the Ouita coal. It has received little attention. The upper bed has, however, been worked at the Shinn mine and other places to supply local demands. The aggregate thickness of the coal varies from 18 to 20 inches but it is generally divided by from 4 to 8 inches of shale.

Away from these two coal localities in Pope county, and in the eastmost townships of Johnson county, coal has not been struck in this shale division. Its extension is therefore problematical; but its absence remains yet to be proved. Though the prospects for finding it are not very flattering, they are sufficiently so to warrant judicious prospecting. Search

should be confined at first to the vicinity of the line separating this shale division from the underlying sandstones.

Overlying this lower coal bearing division is a succession of beds of sandstone and of shale of varying thickness and of irregular distribution. A few thin coal seams are associated with these shales, but exposures are too few and scattered to permit their distribution to be defined. The Pickartz drift, located about seven miles northwest from Coal Hill is an opening in such a bed of some local importance. The coal is about 2 feet thick.

Similarly, below this coal division, coal is known to exist and is dug for local purposes. Near Atkins such a bed is worked belonging below the division numbered III on the map. It is not over 18 inches in thickness, however, and gives no promise of becoming commercially important. The coal which occurs in the hollow between Mount Nebo and Spring mountains, west of Dardanelle, belongs to the same bed.

CHAPTER III.

THE COAL INDUSTRY.

The existence of coal in Arkansas was probably known to the earliest settlers. The outcrops washed bare in the creek beds, the associated smutty soil, the profusion of "float" specimens and other such indications would naturally attract attention. There is written notice of its occurrence as early as the year 1818. With the profusion of easily accessible fuel in the forests, and with the contemporary ignorance of its properties, coal must have been regarded merely as a curiosity for many years, and its full economic value not at all appreciated. In fact, to the present day, a large number of Arkansas coal openings are worked merely to supply the demands of local blacksmith forges. That a workable bed of coal can, with the proximity of a railway, enhance the value of land to many times its surface value, is only now becoming appreciated, when the people are beginning to see how eagerly the control of these lands is sought by speculators and coal companies.

The development of the coal industry on anything like a commercial scale is, however, of recent date. Perhaps the first opening deserving mention was the old Spadra mine, located at the mouth of Spadra creek in Johnson county, where a steam plant was in operation about the year 1870. Mining at Ouita in Pope county was carried on in the year 1873. Soon after the extension of the Little Rock and Fort Smith railway, about 1873, coal from the Coal Hill mines began to seek a market. It was first hauled in wagons to the railway from the Allister slope, but not until the year 1883 did the production from this and other adjacent openings begin to assume commercial importance. These developments, however, were all adjacent to the line of the Little Rock and Fort Smith railway. The western or Sebastian county coal area

remained comparatively unopened even up to this late date. It is true that a number of small mines were opened in Long prairie and one in Massard prairie, which produced collectively, perhaps, 8000 tons per annum. This was hauled in wagons mostly to Fort Smith, however, and little of it reached a more distant market. But, prior to the extension of the St. Louis and San Francisco railway southwards from Fort Smith in 1887, and with the rumor of other railway lines to be built, the attention of coal men became drawn to this area, and during the past three or four years the country has been overrun by speculators, land jobbers and prospectors; drill holes have been put down, and lands bonded and optioned. As an cut-come of this, extensive mining operations have been started within the past eighteen months at Huntington, Hackett City, and near Jenny Lind in Long prairie.

The principal coal producing districts may be conveniently classed as follows:

1. The Western or Sebastian county district;
2. The Coal Hill district;
3. The Philpott district;
4. The Ouita district.

The Western or Sebastian County District.

The Western or Sebastian county district includes the Huntington, the Hackett City, and the Long prairie or Jenny Lind coal mines.

The Huntington coal mine is in the southeast corner of township 5 north, range 31 west, on an extension of the St. Louis and San Francisco railway. It is designated by number 6 on the small map accompanying this report. This mine is owned and operated by the Kansas and Texas Coal Company. The coal is opened by two slopes and one shaft located near the southern outcrop of the coal, each provided with a separate hoisting plant. A large amount of coal has also been obtained by stripping, but the product thus obtained is soft, slacks easily, and is generally an inferior fuel.

The following section of the coal bed was measured by the Survey in the main entry of slope No. 19:

	Feet.	Inches.
Good coal	4	
Shale		10 to 12
Coal		6 to 8
Shale		4 to 6
Coal (best)	2	

The dip at this locality is about 5° northwards.

A sample of this coal was collected from two market cars, and included specimens from all the different benches. The results of analysis are given under number 6 in the table of coal analyses. For further information as to the coking and steaming qualities of this coal, reference should be made to Chapter V of this report.

Numerous pits have been dug in this coal and other small openings made during past years within a few miles of Huntington, for supplying local demands. A complete description of these and of other provings, will be given in the final report. From two such openings samples were collected for analysis by the Survey, *i. e.*, from the Gwyn drift and the Claiborne pit, which are located on the map and designated, respectively, by the numbers 13 and 7. The results of analyses and other information concerning them will be found in the table.

The Hackett City coal mine is near the Indian Territory line, a little southwest of the center of township 6 north, range 32 west, on the same extension of the St. Louis and San Francisco railway as is the Huntington mine. It is designated by number 4 on the accompanying map.

This mine is owned and operated by the Kansas and Texas Coal Company. The principal opening is a shaft over 150 feet deep to the coal, which was provided with a good steam hoisting plant, a ventilating fan, and other surface improvements. This shaft was abandoned during the autumn of 1888, and another opening started in the outcrop of the coal by a slope located about half a mile northeastwards from the shaft. The thickness of the coal here is, on the average, about 3 feet. The dip is southwards at an angle of about 10°. A sample for

analysis was collected from five market cars at the shaft, and represents a fair average of the shipments. The result of this analysis is given under number 4 in the table.

The coal basin in which Hackett City is located broadens and deepens westwards into the Indian Territory, but eastwards, towards Greenwood, it contracts rapidly. The same coal bed is opened near its north outcrop by a shaft at Greenwood and by another known as McConnel's, east of that place. It is also struck, on its south outcrop, in Page's pit, just north of Devil's Backbone ridge. These openings are located on the map and are numbered 10, 9, and 2, respectively. Samples for analysis were collected from each of these openings, and are correspondingly numbered in the table.

The Long Prairie or Jenny Lind coal mines are located near the south line of township 7 north, range 31 west, along the southern outcrop of the coal bed. The principal opening is a slope of the Western Coal and Mining Company, on the line of the Gurdon and Fort Smith branch of the St. Louis, Iron Mountain and Southern railway. This slope was started late in the Autumn of 1888, and will soon be equipped and sufficiently developed to furnish a large amount of coal for the market. This mine is in the same coal bed as, and closely adjoins the Petty slope, which is one of the small openings supplying Fort Smith with coal. It is located on the map and designated by number 17. The following section of the coal bed was measured here by the Survey:

	Feet.	Inches.
Fissile shale.		
Coal	2	6
Shale		2
Coal	2	6
"Black jack" (shale)		3

The dip of the coal is about 9° northwards.

The results of analyses are given under the same number in the table. For a full description of the steaming, coking, and other qualities of this coal, reference should be made to Chapter V.

There are numerous other small openings in both the western and eastern extension of this bed. Of these are located on the map the shafts on the Bocquin and Reutzel property, designated by number 12, Watt's Slope, number 19, and Carnall's drift, number 1. Analyses of samples from these openings are given, under corresponding numbers in the table. They will be fully described, along with a number of others, in the final report.

The Coal Hill District.

The Coal Hill district is taken to include the mines in the immediate vicinity of Coal Hill and also those about Spadra.

The Coal Hill mine, at the town of Coal Hill, is in township 9 north, range 25 west, on the line of the Little Rock and Fort Smith railway, and is numbered 23 on the map. It is owned and operated by Stiewel & Co. The coal is opened by a shaft 168 feet deep. It is provided with a steam hoisting plant rated at 50-horse-power. Also with a 10-foot ventilating fan. Several other shafts have been sunk to the coal in this vicinity but are now abandoned. The aggregate thickness of the coal is something less than four feet, as is shown in the following section:

	Inches.
Coal	21 to 22
Shale and coal	4
Coal	24 to 25

The bed lies in a nearly horizontal position with a good roof throughout the mine.

This coal was carefully sampled by the Survey from one market car and the results of the analysis are given under number 23 in the table. A full discussion of its steaming and other qualities will be found in Chapter V.

The Allister or the Ouita Coal Company's mine is about two miles from the town of Coal Hill, on the west line of township 9 north, range 25 west, at the end of a siding from the Little Rock and Fort Smith Railway. It is designated on the map by the number 24. The bed worked here is the same as

that at Coal Hill. The following section gives the general limited thicknesses:

Shale.

	Inches.
Coal	18 to 24
Shale	2 to 18
Coal	20 to 24

The openings consist of two slopes, or main entries, which follow the coal from the outcrop downwards and northwards with the dip, which is about 2°. A steam hoisting plant is provided at one slope, but coal is hauled out from the other by mules. A sample of this coal for analysis was collected by the Survey from one market car. The results are given under number 24 of the table.

The steaming and other qualities of this coal are similar to those of the coal from Stiewel & Co.'s shaft, with the exception that some of the coal here is softer and slacks more readily on account of its being mined from near the outcrop. With this exception the discussion of the properties of the Coal Hill coal is applicable to this.

The Felker mine, designated by number 20 on the map, is nearly a mile north of the Allister mine, near the east line of township 9 north, range 26 west. The coal is only about 20 inches thick and is interpreted to overlie the bed at the Allister slope and at the Coal Hill shaft. It dips a few degrees north, northwestwards. The coal is worked intermittently for special and local purposes, and is hauled in wagons to the railway, which is about a quarter of a mile distant. It is now handled in Little Rock by the Black Diamond Coal Company, and gives much satisfaction in domestic use. The analysis of a sample collected by the Survey is given under number 20 in the table.

The Eureka or Spadra coal mine is number 22 on the map. It is in the eastern portion of township 9 north, range 24 west, on the line of the Little Rock and Fort Smith railway. The coal is opened by a shaft which is 56 feet deep. The bed dips very slightly to the northwest and has an excellent roof. The

following section represents the general limiting thicknesses:

	Inches.
Coal	16 to 18
Shale	$\frac{1}{2}$ to 2
Coal	18 to 21

Hoisting is done with a small steam plant and ventilation is effected by natural draught.

It is owned and operated by Stiewel & Co.

A sample for analysis was collected by the Survey from one market car and the result is given under number 22 in the table. Further reference to the composition and adaptabilities of this coal will be found in another part of this report.

Several other openings have been made on this coal in the vicinity of the Eureka shaft, but they are all fallen shut now. Among these are the old Spadra workings, at the mouth of Spadra creek, and the Excelsior and Montana shafts, close to the railway and a little west of the Eureka.

Further there are numerous small pits and wells in which coal has been struck, and which may be included in this district. It would be out of place to describe them all here. Mason's drift, numbered 25, and Harkreader's well, numbered 26, are located on the map. Samples for analysis were collected from these openings and the results are given under the same numbers in the table.

The Philpott District.

The Philpott district is taken to include a number of small openings which are scattered over townships 10 north, ranges 25 and 26 west. The beds are thin and the coal production small; but, by reason of the quality of the coal and local facilities for mining, it is able to find a wider market than one would suppose. And this, notwithstanding the fact that it has to be hauled over six miles to the railway at a cost of $2.00 per ton.

The Philpott Mine is the principal one in this district. It is numbered 18 on the accompanying map. The coal is opened by a drift and by a shaft 25 feet deep. The dip of the bed is about 4° northwards. The thickness varies between 20

inches and 2 feet. Hoisting is done by horse and gin. A sample was collected from a large pile of fresh coal at the mouth of the shaft and the results of analysis are given under number 18 in the table.

Moomaw's Pit, numbered 15 on the map, is in the same bed of coal and is there about 20 inches thick. An analysis of a sample from this opening will be found in the table.

Pickartz's Drift is also included in this district and is located, and numbered 5, on the map. The coal here is represented by the following section:

	Inches.
Coal	20 to 22
Shale parting	¼ to 2
Coal	1 to 4

The drift is worked only intermittently and the coal is mostly hauled to Ozark and sold there for domestic uses. The dip of the bed is about 9° northwards, and it underlies the Moomaw and Philpott coal by several hundred feet. The analysis of this coal will be found under number 5 in the table.

The Ouita District.

The Ouita coal district includes the openings at Ouita and those in the Shinn basin south of Russellville.

The Ouita Coal Mine is in the southwest corner of township 8 north, range 20 west, close to the Little Rock and Fort Smith railway, and is numbered 21 on the map. It is owned and the output is controlled by the Ouita Coal Company. The principal opening is a slope, about 500 feet long, which enters the coal near the outcrop, and this is provided with a steam hoisting plant. The dip of the bed is about 5° northwards. The following section gives the general limiting thicknesses:

	Inches.
Clay ("mining")	3
Shale	4
Bony or "wild" *coal*	4
Coal	26
Shale	—

A sample was collected from one market car for analysis. The results are given under number 21 in the table. A full discussion of the qualities of this coal will be found elsewhere in this report. A number of small openings have been made in this bed, principally in its eastern extension from this slope. Their output was small, however, and they are of interest only in relation to the distribution of the coal, and are, hence, not described here.

The Shinn Mines include a number of small openings in a little isolated coal basin, about two miles south of Russellville. They are adjacent to a small branch railway which extends from Russellville to Norristown. Their location is shown on the map by the number 27. The coal aggregates in thickness about 18 or 20 inches, but has generally a shale parting from 4 to 8 inches thick. It dips southward at an angle of about 10°. At Mr. Ed. Shinn's mine a small steam plant is in use, but it is worked only at intervals. The coal is opened by a slope. Most of the output is sold in Russellville and Dardanelle. The analysis is given in the table.

The Production of Coal.

The production of coal on a commercial scale in Arkansas can hardly be considered to antidate the year 1883, and from that time to the latter part of 1887 the production was almost entirely confined to the mines of Johnson and Pope counties. In the fall of 1887 larger operations were started in Sebastian county, and the production from that county may be expected to increase rapidly during the next few years. No statistics are available prior to 1887. In the report of the United States Geological Survey on the mineral resources of the United States for the year 1886, the production of coal for 1885 is given at 100,000 tons, and for 1886 at 125,000 tons. In the same report for the year 1887 the production is placed at 150,000 tons.

The latter estimate is manifestly too high, as is seen by comparison with the figures given below. Those of the preceding years must be even more so.

The figures given in the following table are mostly from the returns of individual operators, and though not all exact, they lay claim to being far more accurate than any results heretofore published. They give a fair general idea of the present condition of the industry in the State.

ARKANSAS COAL STATISTICS FOR 1888.

Counties and Collieries.	Operators.	Total Production in 1887.	Statistics for 1888.							
			Total Production.	Average Daily Production.	Average Number of Hands.	Wages Paid Miners per Ton.	Wages Paid Day Hands per Day	Average Cost of Production per Ton	Average Open Price on Cars at Mine per Ton.	Total Value of Product.
SEBASTIAN COUNTY.		Short Tons.	Short Tons	Short Tons		$	$	$	$	$
Hackett City mine	K. & T. Coal Co.	21,000	38,991	125	104	.87	1.50 to 2.50	....	....	
Huntington mine	K. & T. Coal Co.	12,000	114,783	368	504	.87	1.50 to 2.50		....	
Gwyn drift	W. P. Gwyn	300 *	320	....	5*	...	....	1 50	3.25	
Petty slope	E. B. Petty	3,200 *	6,500	20 to 30	15	.75	......	1.37	2.00	13,000
JOHNSON COUNTY.										
Allister slope	Ouita Coal Co.	49,000	56,237	183	130	.70 to .90	1.00 to 1.50	1 20	1 45	81,544
Coal Hill shaft	Stiewel & Co.	30,000	45,000 *	....	100*	.80	....	...	2.00?	
Eureka shaft	Stiewel & Co.	1,500 *	3,200	....	25*	.80	....	....	1.75 to 2 25	
Felker slope	Black Diamond Co.	1,000 *	1,000 *	....	10*	1.10	....	......	2.50	2,500
Philpott shaft	L. S. Philpott	400	600	15	15	1 25	75 to 1.00	1 50	2.50	1,500
POPE COUNTY.										
Ouita slope	Ouita Coal Co.	4,000	6,040	40	25	1.00	1.00 to 1.50	1 45	2.00	12,080
Shinn slope	J. L. Shinn	200 *	200 *	10	5	...	....	....	....	
Balance from about 25 small openings in different counties	....	4,000	4,000	....	40*	....	.....	....	...	

*Estimated.

Total production in 1887........ 129,600 short tons.
Estimated spot value in 1887....$194,400.
Total production in 1888 .... 276,871 short tons.
Estimated spot value in 1888....$415,306.
Total number of employes in 1888, 978.

The following is a statement of the number of tons of Arkansas coal shipped from points on the Little Rock and Fort Smith Railway during the years 1887 and 1888. The figures for the latter year were furnished by Mr. C. G. Warner, General Auditor of the Missouri Pacific Railway Company:

	1887	1888
From Fort Smith................	140	91
From Coal Hill................	45,998	67,963
From Spadra...................	1,309	3,205
From Ouita (Russellville)........	2,577	3,885
Total....................	50,024	75,144
Amount of coal consumed on the Little Rock and Fort Smith Railway....................		17,064
		92,208

The last figure does not include the amount consumed on the Iron Mountain and Southern Division of the Missouri Pacific Railway.

The carriage of Arkansas coal over the St. Louis and San Francisco Railway during the year 1887 was 18,400 tons. The amount carried during the year 1888 could not be obtained.

The Markets.

The markets reached by the Hackett City and Huntington coals are in Texas, Kansas and Arkansas, the greater portion going to Texas. They are used for steaming and domestic purposes.

The Gwyn drift is worked merely for local blacksmithing and domestic uses.

The Petty slope supplies coal to Fort Smith, Greenwood, Van Buren and other places in the neighborhood, and is used for steaming and domestic purposes.

About two-thirds of the product of the Allister slope is used by the Missouri Pacific Railway, about two-ninths goes to Little Rock and the balance is shipped to Hot Springs, Van Buren, Morrilton, Argenta and other points in the State. About eight-ninths is used for steaming and about one-ninth for domestic purposes.

The product of the Coal Hill shaft is distributed probably in about the same manner as that of the Allister slope.

The coal from the Eureka shaft is shipped mostly to Little Rock, but recently several car load lots have been sent to a number of points in Texas, Missouri, Kansas, and even as far as Nebraska. It is used chiefly for domestic purposes and also for special purposes where free burning, smokeless coal is desired.

The Felker coal is shipped to Little Rock and other points along the railway and is used in about equal portions for domestic, blacksmithing and forge purposes.

The Philpott coal is distributed to different points along the Little Rock and Fort Smith Railway and is used chiefly for blacksmith purposes.

The coal from the Ouita slope in Pope county is shipped mostly to Little Rock, solely for domestic uses. The remainder goes to Van Buren, Russellville, Hot Springs, and to Memphis. In Memphis it has been used on dummy lines. It has also been shipped to St. Louis for railway car stoves.

The small product of the Shinn mine is entirely consumed in the adjoining towns of Russellville and Dardanelle.

The geographic position of the Arkansas coal lands is often emphasized as favorable to the development of a large coal trade, because of their remoteness from the great coal-producing areas of the country, and further, because they form geographically the nearest source of supply for the more southern states in which marketable coal is scarce or entirely absent. This advantage is offset to a great extent in the East through the competition of the Mississippi river traffic, that great channel of trade making the Pittsburg coal of Pennsylvania more accessible to New Orleans than is Arkansas

coal. Railway rates also tend to block the extension of the Arkansas coal trade. Further, in the West, the development of coal in the Indian Territory brings active competition into Texas markets. These conditions will be modified to a certain extent in the future, as new lines of communication are opened up, but they will always exist to a great extent. A most promising line of growth of the Arkansas coal trade in the future will be through the increase of home consumption, with the general industrial development of the State, and also through a careful consideration of the special adaptabilities of the different coals.

CHAPTER IV.

THE COMPOSITION OF ARKANSAS COALS.

The composition of a coal, as ordinarily given, is not a complete index to its adaptabilities. For in addition to the fact that chemical analysis does not reveal purely physical properties, it seems as yet beyond the reach of analytical chemistry to determine the exact combination in which the various constituent elements of coal exist in that complex substance, and hence to estimate the exact effect of those elements upon the calorific power or other properties of this fuel.* An elementary, or ultimate analysis, which gives the amount of each chemical element in a coal, seems to be the closest approach practicable. But for commercial purposes the approach is hardly sufficient to justify the extra cost of such analysis over what is known as a proximate analysis. This proximate analysis determines simply the proportion of those products of a coal which have most important bearing upon its uses, irrespective of their ultimate chemical composition. These substances as usually presented in an analysis are:

Moisture, or water.

Volatile combustible matter.

Fixed carbon.

Sulphur.

Ash.

In addition to these facts relating to composition the following physical properties are generally given:

Specific gravity.

Strength or hardness.

Color of ash.

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*See paper on the Valuation of Coal. By Prof. Charles E. Monroe, U. S. N. A. Proc. U. S. Naval Institute, Vol. VI. No. XIII.

The determination of these eight factors gives a fair, general idea of the adaptabilities of a coal.

Coal is used for the production of steam and in the manufacture of iron; for the latter mostly, after being converted into coke, but also in the raw state. Its other uses are for domestic purposes and for the production of illuminating gas.

The relations to its different uses of these various component parts of coals and of their physical properties will be considered in the discussion of the following table of analyses of Arkansas coals:

A Discussion of the Table of Coal Analyses.

The samples of the annexed table* are from points in the rincipal mining districts of the State, and represent the chief coals of commercial value, so far as they are now known. The existing mining districts are designated as follows:

1. The Sebastian county coal district.
2. The Coal Hill coal district.
3. The Ouita coal district.
4. The Philpott coal district.
5. Outlying and intermediate localities.

From the Sebastian county district, samples Nos. 1, 2, 4, 6, 7, 9, 10, 12, 13, 17 and 19 were collected; from the Coal Hill district, samples Nos. 20, 22, 23, 24, 25 and 26; from the Ouita district, samples 21 and 27; from the Philpott district, samples 5, 15 and 18, and from outlying and intermediate localities, 3, 8, 11, 14 and 16.

The exact location of the various openings is shown on the map accompanying this report, and their relative economic value may be judged of from the thicknesses of the coal beds noted in the table of analyses.

The samples from which these analyses were made were all, with two exceptions, gathered by the writer, and it was his aim throughout to collect as fair an average of the merchantable coal as conditions would permit. Many of the false impressions concerning a coal and most of the discrepancies between different analyses of coal from the same mine, arise from faulty or from different methods of taking a sample. If a mineralogical specimen is desired, any single clean and fresh piece of coal will answer. If the composition of a cross-section of the bed is is to be determined it is best to take a a sample consisting of many small pieces, from some fresh face in the mine; these pieces being taken in one lot, or, if desired, grouped into separate lots, according to their place in the section But, where an analysis is desired of the commercial pro-

*The analyses of the Arkansas coals of this table were made in the laboratory of the Survey by Dr. R. N. Brackett and Mr. J. Perrin Smith. Those of the coals in the "reference list" are from the various sources named in the table.

duct the sample should be taken from the commercial product itself.* The following samples were collected with this idea always in mind. Where possible they were taken directly from the market cars which stood ready for shipment, in other cases from large piles which stood on the dump. At times, however, no such commercial lot was on hand and the sample had to be taken directly from the bed, from some small remnant pile, or even from scattered fragments. The method of sampling is noted with the analysis in each case.

In addition to the chemical results proper, will be noticed in the table certain results of coking tests. These were laboratory tests made in a Hessian crucible with a Fletcher furnace. Their object was to obtain a rough idea as to the coking possibilities of these coals. For comparison similar tests were made of West Virginia Pocahontas coal, and of Pittsburg coal, two representative coking coals. The results of these two tests are appended to the table. The method of work was to heat 50 grams of the pulverized coal in the furnace, at the full heat of the burner for 20 to 30 minutes, until no more fumes were given off. The product was weighed, broken, and its appearance noted. For a description of methods of analysis, etc., reference is made to the report of Dr. Brackett, the chemist.

The basis of classification of these coals is the one which ranks a coal according to its fuel constituents, or, more definitely, according to the ratio between its fixed carbon and its volatile hydrocarbons. On this idea the following scheme has been offered :†

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*Most of the samples of the anthracite coals of Pennsylvania analyzed by the Geological Survey of that state were collected by the writer in this way. A hod or so of coal was taken from each of 10 or more market cars, spread on a platform, broken to uniform size and quartered down to a portable bulk as with any other metallurgical sampling. See Annual Report for 1885, Geological Survey of Pennsylvania, p. 312, or Trans. Am. I. M. E., Vol. XIV, p. 716.

†See paper on Classification of Coals, by Persifor Frazer, Jr. Trans. Amer. Inst. Mining Engrs., Vol. VI, p. 430. Also Report M M., of the 2d Geological Survey of Pennsylvania.

Classes of Coal.	*Fuel ratio*$=\dfrac{\textit{Fixed Carbon.}}{\textit{Volatile hydrocarbon.}}$
Hard dry anthracite	from 99 to 12
Semi-anthracite	from 12 to 8
Semi-bituminous	from 8 to 5
Bituminous	from 5 to 1

This scheme has been used in the classifying of Pennsylvania coals, but even there it cannot be made to regulate trade distinctions. Coals which according to this method of classification are semi-anthracite, are classed in the trade as anthracites, and coals which by composition are bituminous are classed as semi-bituminous. The practical objection to this scheme is that it distinguishes coals entirely according to their proximate composition; whereas, in the trade, the action of the coal in its various uses is the distinguishing property. And it is a well recognized fact that the coals of the same proximate composition will, owing to some inscrutable details of composition, yield different results in practice. Further, competition and prejudice enter, at present, too much into the question for it to be possible to make any scientific classification that will suit all wishes. The following expresses, in a condensed form, the general meaning in the trade of various terms applied to coal:

Anthracite coal is characterized by a low percentage of volatile matter, high specific gravity, hardness, nearly metallic lustre, semi-conchoidal fracture. It ignites with difficulty, produces an intensely hot fire, gives off no smoke, burns with a very small blue flame, which disappears after thorough ignition. Fragments of this coal retain their shape until consumed.

Semi-anthracite coal is not so dense nor so hard as anthracite; the percentage of volatile matter is greater, fracture often approaching the cuboidal. It ignites more readily than anthracite, and burns with a thin yellowish flame at first, which disappears on thorough ignition. Fragments change their shapes very little or not at all during combustion.

Semi-bituminous coal is less dense, and has a higher percentage of volatile matter than the semi-anthracite. Fracture cuboidal. It ignites easily, burns with a yellow flame, and swells or cokes to a certain degree during combustion.

Bituminous coal is characterized by a low specific gravity, and is brittle, with a cuboidal fracture, bright resinous lustre, and a high percentage of volatile matter. It burns with a long yellow flame, giving off more or less smoke. It is usually quite soft, and generally swells, fuses and cokes in the fire.

Coking coal swells and fuses in the fire, and, when air is excluded, the gaseous products are driven off, leaving the carbon in a coherent, porous mass. A coking coal is a caking coal.

Cannel coal is firm and compact, with homogeneous structure; brown to black in color, with a dull resinous lustre. It kindles readily, burns without melting with dense smoky flame, and splits in the fire. It breaks in all directions, with no particular lines of fracture. It is an excellent gas coal, and is rich in hydrogen. It contains 40 to over 50 per cent. of volatile matter, and only a low percentage of moisture.

Lignite or brown coal is a link between peat and bituminous coals. It is compact or earthy, sometimes wood-like in appearance, with a conchoidal or uneven fracture, and may be either cleavable or uncleavable. Its color is light yellow, light gray, brown, brown black or black with a dull, shining or fatty lustre, with a specific gravity from 1.2 to 1.4. It is generally fragile and crumbles readily when exposed to the weather, and contains a large amount of moisture, varying from 10 to over 30 per cent., and consequently yields only a moderate heat. It kindles readily and burns freely with a yellow flame and comparatively little smoke. Generally it is non-caking. The percentage of volatile combustible matter varies from 25 to over 40, and its fixed carbon from 30 to over 50.

Steaming coal should kindle readily, and burn quickly but steadily, and contain only enough volatile matter to ensure rapid combustion. It should be low in ash and sulphur, and should not clinker.

Coals for domestic uses in stoves and open grates should be capable of sustaining a mild and steady combustion, and of remaining ignited at a low temperature with a comparatively feeble draught.

For purposes of comparison, there is appended to the table of analyses a list of coals with which Arkansas coals are brought into competition; also some typical coals from different parts of the world, which furnish an idea of the composition of coals which are put to various uses.

The samples of coals in the table of analyses are arranged consecutively according to their fuel ratios; and, perhaps, one of its most striking features is the preponderance, with reference to proximate composition, of semi-bituminous coals and the fact that only in one locality, *i. e.*, at the Shinn slope, Pope county, is coal found in a workable bed which, from its composition, can be classed as semi-anthracite. The Spadra coal on Spadra creek, of which Dr. Owen gives an analysis, was not sampled at the same opening, as this is long since fallen shut. The sample No. 22 from the Eureka shaft is from the same bed, however, and is less than two miles from Spadra creek. Dr. Owen gets from the Spadra creek coal a fuel ratio of 11, which means decidedly a semi-anthracite, while from Eureka shaft the coal yields a fuel ratio of only 6.46, which means a semi-bituminous coal. This result of Dr. Owen's has been often quoted, and his remarks concerning it have been somewhat carelessly applied to all Arkansas coals, irrespective of their variations in composition, and coal companies are now shipping, as semi-anthracite, coals which are plainly semi-bituminous. The physical appearance of the different varieties is similar, which, together with the fact that in composition they apparently merge into each other by insensible gradations, has rendered a confusion in nomenclature excusable. To the eye they all present more or less the appearance of a soft, bituminous coal with a cuboidal fracture. There seems to be no approach in any of them to the hard, compact, glistening anthracite with its semi-conchoidal fracture.

But despite these facts of proximate composition there are several coals of this list besides 27, or that of the Shinn slope, which, from their manner of burning, deserve to be classed as semi-anthracites. These are: 21, Ouita slope; 22, Eureka shaft; and 26, Harkreader's. These coals are not very easy of ignition, as compared with the bituminous coals, burn with a thin, steady flame and do not swell or coke.* The remaining examples are all of the nature of semi-bituminous coals. Even those termed bituminous in the table are so near the border line as not to have the characteristics of that class at all pronounced. Others, from the Coal Hill district, namely 20, 23, 24 and 25 approach nearer to being semi-anthracites.

On further study of this table in detail and omitting consideration of Nos. 1, 8, 11, 25 and 26 as imperfect† samples, it is seen that the fuel ratio is, as a rule, approximately the same in samples from the same coal bed, when taken from openings not far apart. Thus the coals from the Greenwood shaft (No. 10), and McConnel's shaft (No. 9), have been shown to be of the same bed and are within three miles of each other. Their fuel ratios are 5.10 and 5.09 respectively. Huntington slope (No. 6), Claiborne's pit (No. 7), and Gwyn's drift (No. 13), are all in the same coal bed, and within seven miles of each other.

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*It is a remarkable fact, in this connection, that while the Ouita and Eureka coals are much less free burning and do not fuse or swell in the fire as does the Coal Hill or Allister coal, they yet have a considerably higher percentage of volatile matter, as expressed by the fuel ratio. This is in part due to the manner in which the volatile matter is held in the coal. In the Coal Hill coal it is given off freely at a comparatively low temperature, while in the Ouita coal it takes a long and high heating to drive it off.

†These samples were from coal that had been dug for a year or more and had suffered more or less from the weather. The practical effects of such weathering are to diminish the quantity of carbon and disposable hydrogen, and to increase the quantity of oxygen and indisposable hydrogen, which means a loss of calorific power. Further the coking power of a coal is reduced and finally destroyed and the coal disintegrates. Sometimes there is an increase of absolute weight and of the percentage of ash. The amount of these changes is variable, and with the coals in question they are probably not of sufficient magnitude to seriously affect their classification; but for the sake of safety they are omitted from this discussion. See paper on "Atmospheric Oxidation or Weathering of Coal. By Dr. James P Kimball, Trans. Amer. Inst. Mining Engrs., 1880, Vol. VIII, p. 204."

They have, as fuel ratios, 4.99, 5.04 and 5.29 respectively. The coals at the Coal Hill shaft (No. 23), and at the closely adjoining Allister slope (No. 24), have fuel ratios of 7.02 and 7.30 respectively.

There seems to be some relation traceable between composition and vertical position of the coals. The coal of the Felker slope (No. 20) has a fuel ratio of 6.15, while that of the Allister slope (No. 24), which is considered to underlie it by several hundred feet, has a fuel ratio of 7.30 or, in other words, is more anthracitic. The inference from this instance is offset, however, to a certain degree by a comparison of the analysis of the Moomaw coal (No. 15) with that of the underlying Pickartz coal (No. 5); the fuel ratio of the former is 5.36 or greater than that of the latter, which is 4.97. The difference is not so large as in the former comparison, but the result means that the underlying coal contains more volatile matter.* But, proceeding from these individual cases to the general rule, all the higher numbered or least bituminous coals (from No. 21 to No. 27, inclusive) are, from stratigraphic data, interpreted to underlie most of the lower numbered or more bituminous coals. It is difficult to say, however, whether this relation is a result of stratigraphic position or of geographic location. The more western coals include most of the bituminous and the semi-bituminous, which are highest in volatile matter; while in contrast the more eastern or the Franklin, Johnson and Pope county coals, include the semi-anthracite and the drier semi-bituminous coals. Thus the percentage of volatile matter would seem to diminish eastwards.†

This fact is remarkable as being somewhat in opposition to what structural features would lead one to conclude. Thus, the western or Sebastian county area, and especially that part from

*This peculiar and interesting relation is similar to one existing in the Bernice coal basin in Sullivan county, Pennsylvania, between beds A and B. See Annual Report. Second Geological Survey of Pennsylvania, 1885, p. 407.

†In furtherance of this it is to be noted that the coal at McAllister, Indian Territory, which is a direct extension of the Arkansas coal area, has nearly 30 per cent. of volatile matter and a fuel ratio of 2.11, or, in other words, is a highly bituminous coal.

which the coals for analysis were taken, is characterized by a system of rock corrugations which parallels, on a smaller scale, the flexures of the Pennsylvania anthracite regions. Attendant upon this there should be, according to Mallet's theory, much heat developed, with proportional approach of coal to anthracite. In Johnson and Franklin counties there are no such pronounced flexures, in fact there are very few rock folds of any kind and a nearly horizontal stratigraphy characterizes the coal areas. Thus anthraciticism and plication do not seem to be concurrent phenomena here. Whatever may be the origin of the characteristics of these coals, whether due to the proximity of igneous material beneath, as suggested by Dr. Owen, or to chemical composition of the coal or associated rocks, it was evidently a far-reaching cause, for a low percentage of volatile matter is the pronounced characteristic of all the samples analyzed. That the cause was not a very intense one seems proved, however, by the facts that the coal nowhere reaches the composition of true anthracite, that it retains physical appearance of bituminous coal, and lastly the effects of the general cause were in places much modified or largely counteracted by local conditions as above referred to. For a determination of the precise relations between local conditions and coal characteristics, the number of samples and analyses is insufficient. In fact for an adequate treatment of this whole subject of coal composition many more analyses are necessary and it would be desirable to have one or more from every coal opening in the State. Thus correct averages could be obtained which would establish as facts what isolated instances may only suggest.

The Physical Properties of the Coals.

The physical properties of the coals as indicated by the appearance of the samples are very much the same as those of the coal in bulk. Arkansas coals are all more or less soft and friable and not well adapted to long transportation by land, nor would they stand the rough usage of sea shipments. This is, of course, variable in degree at different places, as can be seen by comparison of the special description of coal openings

elsewhere in this report. It also varies with the nature of the roof and the amount of cover over the coal. Surface strippings and shallow underground workings give naturally a soft and friable coal; but as greater depths are reached and the overlying rock grows hard and unweathered, the coal becomes firmer. Much of the coal shipped from Huntington during the past year has been stripped coal, which, being soft and stained, was calculated to injure the reputation of Arkansas coals in the market.

Strength or hardness in coal is valuable in preventing waste. With a soft coal a great deal is ground to dust in digging, blasting and hauling in the mine; still more is lost at the tipple in cleaning and screening. In railway transportation a great deal of the soft coal becomes crushed, which further increases the direct loss, and, in addition, the coal reaches the market in a bad state. On account of this attrition of transportation a very soft coal cannot be separated at the mines into the various sizes suitable for different uses. Hence it all has to be shipped in lumps, and in this condition does not find so wide a sale. For marine use a soft coal is most objectionable as the motion of the ship keeps up a constant process of disintegration. With a non-coking coal, strength is a prime requisite for its use in the blast furnace, and also to prevent excessive loss through the grates in ordinary furnaces.

The Specific Gravity, it is seen, ranges from 1.292 to 1.469, and the average of the 27 samples is 1.331, which means that one cubic yard of this coal weighs variously from 2180 to 2479 pounds, or an average of 2219 pounds. This is about what has been found to be the specific gravity of American bituminous coals and of grades intermediate between them and anthracite *

The specific gravity or the weight of any bulk of a coal as compared with the weight of the same bulk of water, is an im-

*According to Taylor the specific gravity of American bituminous coals ranges from 1.25 to 1.36; of intermediate coals from 1.38 to 1.70 and of anthracite from 1.32 to 1.81. See statistics of coal, p. 93.

Recent analyses of Pennsylvania anthracites show a range in specific gravity from 1.546 to 1.688.

portant factor when there is any restriction of space, as on railway cars and ship bunkers. In the latter it is especially important that a fuel of high specific gravity be used when a long voyage is contemplated and it is necessary to carry as large a stock of coal as possible. A given bulk of anthracite coal will thus weigh from 15 to 25 per cent. more than the same bulk of bitúminous coal, so that from 15 to 25 per cent. more pounds of fuel could be carried in the same space.*

The Percentage of Water in the Arkansas coals is noticeably low. With the exception of No. 1 (in which the large proportion of water is probably due to the weathered condition of the sample) it nowhere reaches 2 per cent., and the average of the twenty-six samples (omitting No. 1) is only 0.95 per cent. This compares most favorably with the results of analyses of coals in adjoining and competing States. The average percentage of water in one hundred and forty nine samples of Ohio coals is quoted as 4.65. In sixty-four Iowa coals it is 8.57 and in one hundred and twelve Missouri coals 3.40.† Illinois coals are notably high in moisture, which ranges from 4 to often as high as 12 per cent. Thirty-eight samples of Kansas coals yielded an average of 4.79 as the percentage of moisture.‡ Ninety-seven samples of Pennsylvania bituminous coals yielded 1.03 as the average percentage of moisture, and thirty-three samples of Pennsylvania anthracites give 3.35 as an average. It will also be noticed (still excepting No. 1) that those samples which were taken from lots that had been exposed to the weather do not show a noticeable difference from the average in the amount of moisture contained, which indicates that these coals are not hygroscopic—an important point in their favor. The value of this low moisture percentage lies in the fact that

*In considering the economic value of high specific gravity, however, care should be taken to see that this is due to density of the fuel constituents and not to a high percentage of ash.

†Report M, 2d Geological Survey of Pennsylvania, 1874, p. 28. Report of Progress in Laboratory.

‡Composition and Evaporative Power of Kansas Coals. By Prof. E. H. S. Bailey and Prof. L. T. Blake. Sixth Biennial Report of the Kansas State Board of Agriculture.

moisture or water in coal has absolutely no fuel value and is an inert constituent which has to be dug, handled and hauled at a constant expense, and is finally driven out at an actual cost of fuel. Every additional per cent. of moisture means 20 pounds of fuel removed for each ton of coal, or some 400 pounds for the car load.

The Percentage of Ash is not particularly low as compared with results of analyses of other coals. It ranges from 3.09 to 14.21 and the average of the twenty-four samples is 6.76. The average percentage of ash of samples from six different mines in the Belleville district of Illinois is 7.6;* of the thirty-eight Kansas coals it is 10.19; of the seventy-six Pennsylvania bituminous coals, about 5.35;† of Cumberland, Md., coal, 6.4; of fifteen Flat Top coals of Virginia, 5.19.‡ Due allowance should also be made for the varying methods of sampling which has its chief influence on the ash percentage. A commercial sample, such as those taken of the Arkansas coals, would naturally contain more ash than a selected specimen of pure coal. A fairer comparison can be made with the Pennsylvania anthracites, of which commercial samples were collected. In thirty-three samples of the Pennsylvania anthracite coal from different collieries, the ash per cent varied from 4.043 to 12.624 and the average was 8.31.§

Ash is another inert constituent, every per cent. of which means 20 lbs. of dead weight to be handled and 20 lbs. loss of fuel per ton of coal, and as the water in coal is finally removed at cost of fuel, so are ashes finally removed at extra cost of labor. It has been estimated that when the cost of stoking coal is 6⅔ per cent. of the cost of coal (coal at $3 per ton and labor at $1 per day), and with cost of handling ashes double that of stoking coal, 5 per cent. of ash will

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*Taylor's Statistics of Coal, p. 425.

†Report M., 2d Geological Survey of Pennsylvania, p. 29.

‡Report on the New River Cripple Creek Mineral Region of Virginia. By Andrew S. McCreath and E. V. d'Invilliers.

§Annual Report for 1885, Pennsylvania Geological Survey, p. 314.

diminish the fuel value of a coal by over 6 per cent., 10 per cent. ash by over 12 per cent., and so on.*

The nature of the ash is also to be considered as affecting the uses of the fuel. In the proximate analysis the color of the ash is generally given, and this color furnishes a rough measure of the amount of iron it contains, which is an important constituent. Where it is desirable to have further knowledge an elementary analysis of the ash must be made. Iron in an ash makes it more fusible and increases its tendency to clinker. In domestic consumption, where the temperature is low, the quantity of ash is of more importance than its quality or fusibility, but, for steaming purposes, where an excessive or melting heat is required, ashes of a clinkering coal will fuse into a vitreous mass and accumulate upon the grate bars in sufficient quantity to exclude the passage of necessary air, so that the practicability of employing a coal at all will often be determined by this one quality of clinkering of the ashes. Under all such circumstances those coals are best the ashes of which are nearly pure white and which contain little or no alkali nor any lime and large amounts of silica and alumina.†

The Percentage of Sulphur in Arkansas coals, as compared with the best coals of the country, is high. The lowest, it will be noticed, is .862 and the highest is 4.958, and the average for the twenty-seven samples is 2.069. In comparison, the seventy-six bituminous coals of Pennsylvania, above referred to, have an average sulphur per cent. of 1.4; the Flat Top Virginia coals have .73 and the thirty-three anthracite coals have an average of about .63 per cent. In Kansas coals it ranges from 2.5 to 5 per cent. The exact condition of the sulphur in the coals cannot be stated from these proximate analyses, but that much of it exists as pyrites is easily seen from observation. This pyrites occurs in thin films between laminæ of coal, but also in lenticular bands and nodules,

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*See paper by Dr. H. M. Chance on the Relative Value of Coals to the Consumer. Trans. Amer. Inst. Mining Engrs., Vol. XIV, p. 19, 1885.

†See "A Practical Treatise on the Combustion of Coal." By William M. Barr, p. 168. Yohn Bros., Indianapolis, Ind.

which, though lying somewhat irregularly in the coal, it would be practicable to remove to a great extent by more careful mining and inspection at the tipple.

Sulphur may, in one sense, be considered a combustible constituent of coal—that is, it will burn with the development of heat and is thus not inert like moisture and ash. But the injurious effects of sulphur in coal much more than counterbalance its heat-producing quality. Sulphur in coal for heating or steaming purposes corrodes grates and boilers, often eating out the bars of the former till they are worthless, and sometimes causing disastrous explosions of the latter. In coke or raw coal for the blast furnace, sulphur is objectionable, as injuring the iron and producing a hot-short pig. Further, on account of this effect on iron, coals high in sulphur are objectionable for forge use. In gas making the sulphur must be removed by purification and every additional per cent. involves extra cost and makes a poorer gas.

Sulphur generally occurs in coal in the form of iron pyrites and the oxidation of this has a powerful effect in causing disintegration of coal, and this oxidation is further liable to produce spontaneous combustion, which may be the cause of much loss where the coal has to be stored in large heaps. Especially in marine transportation is this a source of grave danger.

The Fixed Carbon, even in the most bituminous of Arkansas coals, is high. It ranges from 67.131 per cent. to 81.277 per cent. (omitting reference to No. 1), and the average is 76.276 per cent. This is higher than the average carbon per cent. in any of the coals with which it is brought into competition, excepting, of course, Pennsylvania anthracites, which contain from 78 to 88 per cent. of fixed carbon. In Pittsburg and other Pennsylvania bituminous coals the percentage of fixed carbon averages about 68, and is often below 60. Illinois coals have a still lower fixed carbon per cent., it often being less than 50. Similarly Missouri coals are bituminous, with a comparatively low percentage of fixed carbon, and the 38 Kansas coals have an average of 45.4 per cent.

The fixed carbon of a coal is its principal combustible constituent. In coking coals the percentage of coke yielded is in proportion to the percentage of fixed carbon, and as affecting the coking qualities of a coal the fusibility of the carbon is of great importance. With bituminous and semi-bituminous coals the steaming value is in proportion to the percentage of this constituent, and this even more, perhaps, than careful tests would indicate For, notwithstanding the fact that the fixed carbon of a coal will evaporate much less water than an equivalent weight of the volatile combustible matter when properly burnt, still, in practice, so much of the latter is lost through careless firing, or improper furnace construction, that the relative steaming value of a coal may be fairly approximated by assuming the carbon to be the only useful constituent. The condition of the fixed carbon, as well as that of the volatile matter, decide also whether a coal will ignite easily and burn freely. In other words, whether it be quick steaming or not.

The Volatile Hydrocarbon Per Cent., in inverse proportion to that of the fixed carbon, is low even in the most bituminous samples of our Arkansas coals. It ranges from 8.41 to 16.394 (excluding No. 1), and the average of the 26 samples is 13.739. In comparison, the bituminous coals of Pennsylvania have volatile combustible matter ranging from 19 to over 40 per cent., while 30 per cent. represents about a fair average. In Illinois coals it is generally above 30 and ranges up to 47 per cent., and similarly with Missouri coals. The average per cent. of volatile matter in the 38 Kansas coals is 39.62. In Pennsylvania anthracites it ranges from 2.75 per cent. to 4.68.

Volatile combustible matter constitutes an important part of coal as a fuel. The amount and quality are of first value in deciding whether a coal be suitable or not for the manufacture of illuminating gas. The coking of coal is largely, though not wholly, dependent upon this constituent, as is also the quality of caking in ordinary combustion. Coals with a large percentage of volatile combustible matter are easily ignited and burn with a long yellow flame, but also form much soot in ordinary combustion and give out great volumes of dense

smoke. How objectionable this quality is in fuel for railway use every traveler can testify. For naval purposes such coals are at times proscribed, as the smoke generated is liable to betray the positions of vessels of war when it is desirable that they should be concealed.

The Crucible Coking Tests, the results of which are attached to the table of analyses, do not, of course, establish the capabilities of the different coals for the production of coke on a commercial scale. But the negative results are final. That is, a coal which will not coke in the crucible will not do so in the oven. The positive results, however, establish only a scale of probabilities. These results may, therefore, be interpreted as follows:

Will probably coke.

2. Page's pit.
3. Baxley pit.
5. Pickartz drift.
6. Huntington's slope.
8. Lewis' pit.
10. Greenwood shaft.
13. Gwyn's drift.
14. Carlan's slope.
15. Moomaw's pit.
16. Graves' drift.
18. Philpott's shaft.

Will possibly coke.

4. Hackett City shaft.
7. Claiborne's pit.
9. McConnell's shaft.
11. Sullivant & Boling.
12. Bocquin & Reutzel.
17. Petty's slope.
19. Watt's slope.

Will probably not coke.

20. Felker's slope.
23. Coal Hill shaft.
24. Allister slope.
25. Mason's drift.

Will certainly not coke.

21. Ouita slope.
22. Eureka shaft.
26. Harkreader's well.
27. Shinn's slope.

CHAPTER V.

THE ADAPTABILITIES OF ARKANSAS COALS.

The principal uses to which coal is put are:

1. The production of steam.

2. The manufacture of iron and for other metallurgical purposes.

3. Domestic purposes.

4. The production of illuminating gas.

These uses are mentioned in the order of their importance as measured by the amount consumed. Of these, the first, the production of steam, probably disposes of half the total output of coal in the United States.

The value of a marketable coal is, to a great extent, a relative one, and depends upon the use to which it is to be put. An excellent steaming coal may be an inferior or practically worthless coal for the manufacture of iron, for domestic purposes or for gas production. The same may be true of coals specially adapted to any other of the uses cited. It is therefore of great importance that a coal should be put on the market with a full knowledge of what special class of uses it is pre-eminently fitted for.

Now, Arkansas coals occupy that middle position, among the various types, which combines many of the characteristics of the extremes with characteristics of their own, which the extremes lack. Among these Arkansas coals, and even among those coming from closely adjoining localities, there is moreover a great difference in their capabilities. It therefore behooves all who have interests in these coals to pay careful attention to the uses to which each particular coal is adapted, and those energies will be best spent which look toward making the demand in its special field exclusive and imperative for that special coal. Such activity should include not merely the

direct soliciting of custom, but also the study and the designing for each special coal of the best form of grate or furnace, either domestic or industrial, of the best mode of preparing the coal for market, of the condition in which the coal is best for any use it may be put to, and, in short, all such questions as lead to the development of all that is good and valuable in the coal should be given the most careful attention.

For the Production of Steam.

The results obtained from a coal in practice depend upon:

1. The nature of the coal.
2. The character of the furnace.*
3. The conditions of firing.

With regard to the nature of the coal, the relative amounts of fuel constituents and of inert constituents, such as moisture and ash, and the nature of the fuel constituents and their respective calorific powers, are of chief importance. From this it might be inferred that the evaporative power of any coal may be calculated directly, from a knowledge of the proportion and of the calorific power of each of the component elements of the fuel constituents. But this is not so. The difference between such calculated results and real calorific powers, as obtained from experiments, in which *complete* combustion was insured, amounted in some instances to as much as 15 per cent.† Yet results such as these are calculated out and are liable to be compared, by the ignorant, with results from actual tests, which naturally leads to very erroneous conclusions. Again, another easy method naturally suggests itself for obtaining the evaporative power of coal, *i. e.*, by the use of some form of laboratory calorimeter which determines the heat produced by the *perfect* combustion of coal. But, for practical purposes, such results do not appear to furnish much

*By "furnace" is here meant the whole apparatus for burning the fuel and transfering the heat to the body to be heated, including ash-pit, air holes, flame chamber, flues, tubes and heating surface of any kind, and chimney or stack.

†The Valuation of Coal, by Prof. Chas. E. Monroe, U. S. N. A., p. 225, Proceedings United States Naval Institute, Vol. VI, 1880.

more knowledge of the capabilities of a coal than does a knowledge of its chemical composition. Nowhere in practice is perfect combustion attained; and, further, it is a striking truth, that as most coals are burnt, the very constituents of the fuel which have the highest calorific powers, the volatile combustible matters, yield less economic effect than does the constituent which has the least calorfic power, the fixed carbon.* Hence, a large proportion of the heat developed in the calorimetric test is lost in the furnace. But the most important defect of such laboratory tests is that they do not furnish any information as to the behavior of the coal in the furnace. Thus no knowledge can be derived from them of the form of furnace and method of firing best adapted to the coal. Calorimetric determinations of the evaporative power of coals are abundant and are frequently referred to. It is sometimes claimed that even though the results they offer cannot be taken as an absolute measure of the efficiency of a coal, they are at least of relative value when applied to the different coals tested. This may be true when such tests are of coals having very similar characteristics. But in view of the variable sources of loss in the use of coals of different characteristics, even this relative value would seem to disappear.

An experimental working test with a steam boiler will, next, naturally be considered as a means for determining the steaming value of a coal. But here we are immediately confronted with the question as to what form of furnace and what methods of firing shall be used. The same coal in different furnaces will yield very different results.† Different coals

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*One pound of hydrogen gas will evaporate.......64.2 pounds of water.
One pound of marsh gas will evaporate.........24.3 pounds of water.
One pound of carbon will evaporate.............15.0 pounds of water.
Shock's Treatise on Steam Boilers.

Notwithstanding this fact, however, among the more bituminous varieties, the coals with the high percentages of carbon constitute the best steaming coals.

†Compare Kent's results in Trans. Amer. Soc. Mech. Engrs., Vol. IV., 1883; Isherwoods' Experimental Researches and Reports in Annual Reports of Chief of Bureau of Steam Engineering, U. S. Navy Dept.; Thurston's Manual of Steam Boilers; Shock's Treatise on Steam Boilers; Quartermaster General Meigs' report on Fuel for the Army; and also the results of numerous boiler tests made by John W. Hill.

which may yield closely the same results in different furnaces may yield quite different results in the same furnace. A furnace best adapted to anthracite coals is not best adapted to bituminous coals. The same coal in the same furnace will, with different rates of combustion, evaporate different quantities of water per pound of fuel,* and the differences will not be the same with different coals. Hence an attempt to draw guiding conclusions from an indiscriminate comparison of results of practical coal tests made by different men, under widely different conditions, results only in confusion. And when it is further attempted to draw into the consideration the results of different calorimetric tests the confusion becomes veritably "worse confounded."

The outcome of all this is, simply, that a consideration of the steaming qualities of a coal involves also a consideration of the form of furnace and of all the conditions of combustion.

The evaporative power of a coal in practice can not be truly stated without reference to the conditions of combustion and every practical test of a coal, to be thorough, should lead to a determination of the best form of furnace for that coal and should furnish knowledge as to what classes of furnaces in actual use such coal is specially adapted. It is not sufficient that in comparative tests of coals the same conditions should exist with each, but there should also be determined the best conditions for each coal.

This preamble is not meant, however, to lead to the discouraging conclusion that it is not practicable to reach any general results concerning the evaporative power of a coal. The chief difficulty is in obtaining close results, such as are necessary for fixing the relative values of coals which are nearly of the same composition, and also for expressing *exact*

*Shock in his Treatise on Steam Boilers gives the following illustration of this:

With 6 lbs. of coal per hour per square foot of grate, 10.49 pounds of water per pound of coal were evaporated.

With 24 lbs. of coal per hour per square foot of grate, 6.82 pounds of water per pound of coal were evaporated.

relative values of coals which differ widely as to quality. But the superiority of a coal high in combustible constituents over one low in combustible constituents can be broadly and boldly defined. And, further, as already hinted, it seems to be generally acknowledged in steam practice that the coals with the higher percentages of fixed carbon are most desirable for present general uses. And of those coals high in fixed carbon, the classes to which Arkansas coals belong, the semi-anthracite and the semi-bituminous, seem to rank at least as high as the anthracites in meeting the various requirements of a quick and efficient steaming coal. As a measure of the value of anthracite for steaming purposes Johnson's classical work* is frequently quoted, in which anthracite is recommended for the use of the navy. But even his data give 9.98 pounds of water as the average evaporative power of semi-bituminous coals and 9.56 for anthracites Johnson was, of course, influenced by other considerations of quality which he considered necessary in a fuel for naval purposes. But, as a result of recent investigations, under modern conditions, even this decision as regards this special use is changed and the use of semi-bituminous coal is recommended.† This is done on consideration of the high heating powers of such coals combined with the qualities of promptness of ignition, considerable density, completeness of combustion and comparatively small amounts of smoke and soot produced. It is recognized, however, that such coals are more friable and deteriorate generally more readily than do anthracites; and also that they are more liable to spontaneous combustion. The semi-bituminous coals here referred to were chiefly the Cumberland, Maryland, and Flat Top, Pennsylvania, coals. For railway use these coals have been found in cases to excel anthracites in evaporating power.

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*Experiments on the Evaporative Power and other Properties of American Coals. Report to the Secretary of the Navy, 1844. By Walter R. Johnson.

†Discussion of the Merits of Anthracites and Bituminous Coals. By Chief Engrs. C. H. Baker and F. G. McKeen, U. S. Navy. Members of Board to report upon the comparative merits of coal for naval use. Office of Naval Intelligence, Bureau of Navigation, Navy Dept., 1888.

The comparative absence in semi-bituminous coals, of smoke, which means loss of combustible matter as well as discomfort to the traveler, is sufficient to suggest the superiority of these coals over bituminous coals for such use. In fact the high rate of combustion and the strong draught necessary in locomotives is particularly unfavorable for the economic combustion of bituminous coals. Such semi-bituminous coals are also specially well suited for small tubular boilers, fire box steam boilers or other forms with small unlined combustion chambers in which the gases from bituminous coals become cooled, are not burnt and deposit soot in the tubes. In short, semi-bituminous coals give excellent results under a great variety of conditions. It does not follow by any means, however, because some semi-bituminous coals yield such good results that all such coals will do so equally ; and, in recognition of this fact, the Survey has had working tests of various Arkansas coals made by the St. Louis Sampling and Testing Works.

The samples for these tests were taken from three different mines, from which the coal was thought to fairly represent the character of the principal workable coals of the State. They were all collected by the writer in person, and care was taken to secure not a picked sample, but a fair average of what was sent to the market. None of it was hand picked. The samples represent the lump coal as it comes from the tipple to the car. As only the ordinary bars were used at these tipples, and the coal not at all inspected on the platforms, naturally more worthless or deleterious material is represented in these samples than would be with a more careful preparation of the coal. Hence better results can be obtained than these samples indicate

The various coal companies liberally furnished the coal for the purposes of these tests free of charge, as well as all necessary help for sampling and handling the same. Sample No. I was hauled from the mine to St. Louis by the St. Louis and San Francisco Railway Company, and samples Nos. II and III by the Missouri Pacific Railway, all free of cost to the Survey.

Acknowledgment is due to these companies for their interest and courtesy in this connection.

Sample No. I was furnished by the Kansas and Texas Company from Slope No. 19 at Huntington, Sebastian county. It was sampled August 9, 1888, from lump coal of one hundred and twenty-three mine cars (equivalent to seven market cars) as delivered to market cars. This coal all came from the top (four foot) bench, which was the only one mined at the time, and was delivered from all parts of the mine. The sample amounted to about five tons in all, and was shipped in a flat-car to St. Louis.

Sample No. II was furnished by Stiewel & Co. from their shaft at Coal Hill, Johnson county. It was sampled August 6, 1888, from eight market cars of fresh coal. The coal was from both benches of the bed, and from all parts of the mine then worked. The sample was shipped to St. Louis in a box-car, and amounted to about three tons in all.

The coal at the Allister slope of the Ouita Coal Company is essentially the same as that from Stiewel & Co.'s shaft. It is from the same bed, and the two mines closely adjoin each other. The workings at the Ouita Company's slope are, however, nearer the surface, and some of the coal shipped, from lack of sufficient cover, is softer than that from Stiewel & Co.'s shaft. Practically the same steaming qualities can be expected from the one as from the other.

Sample No. III was furnished by the Western Coal and Mining Company, and is from the same bed as is opened by their Slope No. 15, near Jenny Lind, Sebastian county. This slope had not reached the coal December 17, 1888, when the sample was collected, and hence it was taken from Mr. E. B. Petty's opening, immediately adjoining, in which the coal is of the same quality. About five tons were selected from a large pile of freshly mined coal, stacked at the mouth of the slope. It represented coal from the deeper portion of the mine, under good cover. It was shipped to St. Louis in a box-car.

The following contains the results of the tests of these coals as reported by Prof. Wm. B. Potter, Manager of the St. Louis Sampling and Testing Works:

1225 and 1227 Spruce Street,
St. Louis, Mo., April 13, 1889.

Arthur Winslow, Esq., Assistant Geologist in Charge of Coal Regions, Geological Survey of Arkansas, Little Rock, Ark.

Dear Sir:—We have made a careful examination and series of tests of the sample lots of coal sent us, and herewith submit a report on the results:

The series of tests, which we have arranged and adopted as a standard for fuels at these works, have the following main objects in view:

1. To determine the chemical and physical properties of each coal.

2. To ascertain its total calorific power by direct experiment in a Thompson calorimeter.

3. To determine by a series of trials, the conditions under which the coal may be used to the best advantage in actual practice under steam boilers.

4. To determine what evaporative efficiency may be expected from the coal when these conditions are fulfilled.

5. To compare the results obtained by the tests of the coal with those determined when using a well known type of coal as a standard.

The determination of the conditions required for securing the most economical use of each coal includes the ascertainment of the best proportions for grate surface and heating surface with given heights of chimney; of the most suitable type of grate; and of the best methods of firing. The determinations require usually two or three complete boiler tests to be made on each kind of coal, varying the conditions until the maximum economy is attained.

The boiler used at these works is a horizontal return tube boiler, 54 inches diameter and 16 feet long with 36 four inch tubes. The boiler has a Jarvis setting and arrangements are made for varying the area of the grate, and for admitting more

or less air above the fire. From the front end of the boiler a horizontal sheet iron flue about 25 feet long, provided with a damper, connects with the chimney, which is of brick for a height of 25 feet, and is surmounted by a 28 inch iron stack extending to a height above the grate of 72½ feet. The grate is a common type of shaking grate, and has about 27½ per cent. air space.

In making the tests, the boiler is run for several hours at full pressure, until all parts of the furnace are thoroughly heated. The fire is then hauled, and a new fire quickly kindled with wood, and the firing begun with coal which has been weighed. The conditions—steam pressure, flue temperature, water level, etc.,—are kept uniform during each test, at the end of which the fire is hauled, and the unburned coal, ashes and clinkers are weighed. Each test is usually continued for eight hours, during which time regular observations are made every half hour of the steam pressure and temperature, water level, temperature of feed water and of flue gases, position of damper, amount of admission opening for air above fire, pressure of draft in flue, density of smoke produced, if any, thickness of the bed of coals on the grate, etc. The manner of firing is carefully observed, and a record of the times of firing each door of the furnace is kept on the log. The temperature of the boiler room and the outer air, the condition of the weather, and the height of the barometer, are also recorded. The coal and water are weighed on separate platform scales, the water being weighed into a tank from which it is pumped into the boiler. Ample precautions are taken to guard against leakage. The percentage of water entrained in the steam is ascertained by a Barrus superheating calorimeter. Samples of the coals and ashes are carefully selected during each test for chemical analysis and for the calorimetric test, and analyses are also made of the flue gases, to determine the degree of completeness of the combustion.

The standard coal adopted is that from the mines of a well known company operating in the Pittsburg district, and may be said to represent fairly the standard steam coal of that re-

gion. The Pittsburg coal has been selected for this purpose for the reason that it is one of the best known and most widely used of the better class of steam coals in this country, and comparison with this as a standard is likely to be more useful on this account.

The proximate analyses of this coal is as follows:

	Per cent.
Moisture	1.80
Volatile matter	35.34
Fixed carbon	54.94
Ash	7.92
	100.00

The calorific power of this coal by Thompson's calorimeter equals: 13 104 British thermal units per pound of coal.

The evaporation under proper conditions to dry steam from and at 212°, F. is:

8.5 pounds of water per pound of coal.

9.1 pounds of water per pound of combustible.

The attrition test adopted consists in charging about 50 pounds of lump coal in a barrel mounted on a horizontal axis through the length of the barrel. This is rotated for half an hour at the rate of twenty turns per minute. The contents are then put through a No. 1 screen, dividing lump from screenings, each of which are weighed. These tests were made at various times after the coals were received. The several lots of coals were kept separate in dry places, carefully protected, and there has been no change whatever in any of the coals from the time they were received to the present time. The following are average results of a number of tests of each coal, including the standard Pittsburgh:

	Pittsburgh, Pa.	No. I, Huntington, Ark.	No. II, Coal Hill, Ark.	No. III, Jenny Lind, Ark.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Lump	79	35	52	41
Screenings	21	65	48	59

These results show that the Arkansas coals are of a comparatively tender character which is characteristic of coals more or less metamorphosed as these have been.

The results of analyses of screenings from the above tests show that as far as composition is concerned there is no deterioration in the screenings from original coals.

Enclosed herewith are tabulated forms giving the results of boiler tests for the several lots of coal. These results are obtained from returns of several trials with each coal. A form giving facts relating to the boiler plant used for these tests is also enclosed.

As compared with the standard coal the following percentage results are given:

Evaporation of water from and at 212° per pound of coal:

Pittsburg.	No. I, Huntington, Ark.	No. II, Coal Hill, Ark.	No. III, Jenny Lind, Ark.
100.0 per cent	96.2 per cent	74.3 per cent	89.8 per cent

*Evaporation of water from and at 212° per pound of combustible:**

Pittsburg.	No. I, Huntington, Ark.	No. II, Coal Hill, Ark.	No. III, Jenny Lind, Ark.
100.0 per cent	100.2 per cent	115.3 per eent	104.9 per cent

All the Arkansas coals so far tested burn quite freely and make a clean, smokeless fire. No special arrangements are wanted for admitting air above the fire with these coals. They do best on a grate with rather small openings, as they are more or less liable to decrepitate, and fall through into the ash pit.

Coal No. II, Coal Hill, is especially troublesome in this respect, as with ordinary grates and firing from 30 to 50 per cent. of the coal will fall into the ash pit unburned. A step grate would probably be best adapted for this coal. With proper treatment on an ordinary grate with small spaces between the

*By the pound of combustible is meant the pound of fuel or combustible constituents actually used in the test, and excludes the amount of coal as well as the ash falling through the grate. This does not make any allowance or deduction for moisture in the coal. It is the standard rating of pounds of water evaporated, divided by the pounds of fuel charged, less the pounds of ash, clinkers and coal falling through the grate, accounting also for that left on the grate at the end of the test.

bars, aggregating about a quarter of the grate area, the Huntington coal and the Jenny Lind coal will not lose more than about 3 and 5 per cent. respectively in this way. With ordinary chimney draft and a grate such as just described, the tests indicate that the best results will be obtained by carrying a bed of fuel about 9 inches thick for the Huntington coal, 7 inches for the Jenny Lind coal and 5 inches for the Coal Hill coal.

The Huntington and Jenny Lind coals are excellent steam coals, adapted either for locomotive or stationary boilers. They would answer equally well in either, but, if there is any difference it would be in favor of the stationary boilers. The Coal Hill coal breaks up too readily and gives rise to too great a loss for economic use, unless some such system as step grate is applied. This would only be practicable in stationary boilers and not in locomotives.

For the Huntington coal the ratio of heating surface should be about 5.3 times the square root of the height of the stacks, for the Jenny Lind coal about 6 times, and for the Coal Hill coal about 4 times, With these proportions, and fairly clean flues, the following evaporative duties may be expected:

For No. I, Huntington, Ark .....8.5 pounds of water per pound of coal.
For No. II, Coal Hill, Ark........7.0 pounds of water per pound of coal.
For No. III, Jenny Lind..........8.4 pounds of water per pound of coal.

The coking tests have been made in a coke oven rectangular in plan with arch roof and four flues leading down side walls and under bottom to flue connecting with stack. This oven takes a charge of 400 to 800 pounds.

The Jenny Lind coal was treated in this oven for 24 hours, several runs being made in charges varying from 400 to 800 pounds. Even with highest heats attainable and thick charges the coke obtained was of poor quality and indeed can hardly be classified as coke. The coal slacks down too readily when heated and there is not enough bituminous matter liberated during destructive distillation to secure a sufficient cementing of the particles. Samples of the "coke" will be sent you. It is sufficiently evident from the tests made on the samples of

Jenny Lind coal that merchantable coke can not be made from it. Respectfully,

ST. LOUIS SAMPLING AND TESTING WORKS,
WILLIAM B. POTTER, Manager.

ST. LOUIS SAMPLING AND TESTING WORKS,
1225 AND 1227 SPRUCE STREET, ST. LOUIS,
April, 1889.

Description of boiler and setting at St. Louis Sampling and Testing Works, 1225 and 1227 Spruce street, St. Louis, Mo.

Kind of boiler, return tubular. Made by Rohan Bros., of St. Louis, 1887.

DIMENSIONS OF EACH BOILER.	Number.	Diameter.	Length.	Material.	Thickness.
Shells	1	54 in.	16 in.	Steel.	
Tubes	36	4 in.	16 in.	"	
Steam Drums or domes	0				
Mud drums	0				
			Width.	Depth.	Height.
Internal fire boxes					
Water legs					

	Shells.	Tubes.	Flues.	Fire Boxes.	Water Legs.	Total.
Heating surface, square feet, each boiler	166.	564.				730.
Preheating surface	0					
Superheating surface	0					

Type of Setting—Jarvis furnace, sheet iron flue from uptake to chimney.

Type of Grates—"Standard" rocking grate bar. *Length*, 4 ft. 6 in.; width, 5 ft.

Means of Producing Draft—Chimney 24x24 inches, brick for about 30 feet above grates, thence iron stack 28 inches diameter extends to 72½ feet above grates.

Grate Surface, sq. ft., 22.5. *Percentage of opening* ...... 27.5........

Draft Openings Above Fire, sq. ft. .42. *Per sq. ft. of Grate*... .018........

Height of Boiler Above Grate ....

Tube Calorimeter, sq. ft. 2.75 ....

Area of Cross Section of Flue, sq. ft...........

TOTALS FOR ONE BOILER.

Heating Surface, sq. ft........... 730 ....

Preheating Surface, sq. ft........... 0

Superheating Surface, sq. ft. .... 0 ..

Grate Surface, sq. ft. .... 22.5 ....

Area of Cross Section of Main Flue sq. ft. ....

Area of Cross Section of Chimney, sq. ft........... 4.25........

Height of Top of Chimney Above Grate.......... 72.5 ft........

ST. LOUIS SAMPLING AND TESTING WORKS,

1225 and 1227 Spruce Street, St. Louis.

Results of evaporative test on Pittsburg coal, made March 30, 1889, by St. Louis Sampling and Testing Works, at works:

DURATION OF TEST	*hours*	8.00
Mean height of barometer	*inches of mercury*	....
" temperature of boiler room	*degrees, F.*	60.00
" temperature of outside air	*degrees, F.*	50.00
" condition of weather		Partly cloudy.
" steam pressure above atmosphere, by gauge	*pounds*	74.40
" temperature of steam	*degrees, F.*	322.00
MEAN ABSOLUTE STEAM PRESSURE	*pounds*	92.50
" height of water level	*inches*	6.40
MEAN PERCENTAGE OF WATER ENTRAINED IN STEAM	*per cent*	2.00
" temperature of feed water	*degrees, F.*	70.00
Pounds of water apparently evaporated	*pounds*	13,000.00
Equivalent evaporation to dry steam from and at 212 degrees, F., 13,000 x 1.165	*pounds*	15,145.00
Equivalent evaporation per hour, 1893.1 pounds	*boiler horse power*	54.90
EQUIVALENT EVAPORATION PER HOUR PER SQUARE FOOT OF HEATING SURFACE	*pounds*	2.60
Weight of coal used, plus equivalent of wood	*pounds*	1,800.00
WEIGHT OF ASHES, CLINKERS AND COAL WHICH FELL THROUGH GRATE, 147 pounds	*per cent. of waste*	8.10
Percentage of unburned fuel which fell through grate	*per cent*	2.10
PERCENTAGE OF CLINKERS IN FUEL	*per cent*	1.90
Mean opening of damper (percentage of full opening)	*per cent*	100.00
MEAN TEMPERATURE OF FLUE GASES	*degrees, F.*	447.00
Mean pressure of draft in flue	*inches of water*	.20
MEAN THICKNESS OF FIRE	*inches*	8.80
MEAN OPENING OF AIR INLETS ABOVE FIRE PER SQUARE FT. OF GRATE	*square feet*	.02
POUNDS OF COAL BURNED PER HOUR PER SQUARE FOOT OF GRATE	*pounds*	16.26
POUNDS OF COAL BURNED PER HOUR PER SQUARE FOOT OF HEATING SURFACE	*pounds*	.30
MEAN SMOKE PRODUCTION ON SCALE OF 10		1.40
Mean Composition of Flue Gases, per cent..N. O, 9.66. CO_2..7.44 .... CO...57.		
EVAPORATION OF WATER FROM AND AT 212 DEGREES, F., PER POUND OF COAL	*pounds*	8.41
EVAPORATION OF WATER FROM AND AT 212 DEGREES, F., PER POUND OF COMBUSTIBLE	*pounds*	9 10
Fuel used: kind		size, 1 in. to 4 in. diam.

Chemical Composition of Coal, ultimate: Per cent. C., 77.05; H., 5.80; O., 7.26; S., 1.97	
Chemical Composition of Coal, proximate: Per cent H_2O., 1.80; Vol., 35.34; F. C., 54.94; Ash, 7.92	
Calorific power of Coal, B. T. U. per lb., calculated by calorimeter....	13,104.00
Theoretical evaporative power, from and at 212 degrees, F........	....
Percentage of total calorific power utilized, or efficiency...........	....

ST. LOUIS SAMPLING AND TESTING WORKS,

1225 and 1227 Spruce Street, St. Louis.

Results of evaporative test on Arkansas coal, No. I, Huntington, Ark., (Geological Survey), made December 15, 1888, by the St. Louis Sampling and Testing Works, at works:

DURATION OF TEST........ *hours*..	6 60
Mean height of barometer........ *inches of mercury*..	....
" temperature of boiler room........ *degrees, F*..	56.00
" temperature of outside air........ *degrees, F*..	43.00
" condition of weather........	Rainy.
" steam pressure above atmosphere, by gauge........ *pounds*..	68.70
" temperature of steam........ *degrees, F*..	315.50
MEAN ABSOLUTE STEAM PRESSURE........ *pounds*..	83.40
" height of water level........ *inches*..	6½
MEAN PERCENTAGE OF WATER ENTRAINED IN STEAM.. *per cent*..	2.00
" temperature of feed water........ *degrees, F*..	171.00
Pounds of water apparently evaporated........ *pounds*..	11,762.00
Equivalent evaporation to dry steam from and at 212 degrees, F........ *pounds*..	12,429.00
Equivalent evaporation per hour, 1883 pounds.. *boiler horse power*..	54.60
EQUIVALENT EVAPORATION PER HOUR, PER SQUARE FOOT OF HEATING SURFACE........ *pounds*..	2.58
Weight of coal used, 1502.5; plus coal equivalent of wood, 16.5........ *pounds*..	1,519.00
WEIGHT OF ASHES, CLINKERS AND COAL WHICH FELL THROUGH GRATE, 156 pounds.... *per cent. of waste*..	10.30
Percentage of unburned fuel which fell through grate..... *per cent*..	3.10
PERCENTAGE OF CLINKERS IN FUEL........ *per cent*..	3.50
Mean opening of damper (percentage of full opening).... *per cent*..	60 00
MEAN TEMPERATURE OF FLUE GASES........ *degrees, F*..	478.00
Mean pressure of draft in flue........ *inches of water*..	0.10
MEAN THICKNESS OF FIRE........ *inches*..	9.00
MEAN OPENING OF AIR INLETS ABOVE FIRE, PER SQUARE FOOT OF GRATE........ *spuare feet*..	.002
POUNDS OF COAL BURNED PER HOUR, PER SQUARE FOOT OF GRATE........ *pounds*..	13.15

POUNDS OF COAL BURNED PER HOUR PER SQUARE FOOT OF HEATING SURFACE	*pounds*	.315
MEAN SMOKE PRODUCTION ON SCALE OF 10		0.40
MEAN COMPOSITION OF FLUE GASES	*per cent*	
N........., O........., CO_2, CO		....
EVAPORATION OF WATER FROM AND AT 212 DEGREES, F., PER POUND OF COAL	*pounds*	8.18
EVAPORATION OF WATER FROM AND AT 212 DEGREES, F., PER POUND OF COMBUSTIBLE	*pounds*	9.12
Fuel used: kind.........; size		....

Chemical Composition of Coal, ultimate:

Per cent., C., 80.7; H., 5.66; O. and N., 3.55; S., 3.44

Chemical Composition of Coal, proximate:

Per cent., H_2O, ...; Vol., ...; F. C., ...; Ash, ...

Calorific power of Coal, B.T. U., per pound, calculated by calorimeter	11,400.00
Theoretical evaporative power, from and at 212 degrees, F.	11.80
PERCENTAGE OF TOTAL CALORIFIC POWER UTILIZED, OR EFFICIENCY	69.30

Ignites readily, burns with a thin, bright flame and but little smoke. Requires little stoking. Small amount of hard clinkers which gives no trouble. Ash fairly clean and somewhat fine.

ST. LOUIS SAMPLING AND TESTING WORKS,

1225 and 1227 Spruce Street, St. Louis.

Results of evaporative test on Arkansas coal, No. II, Coal Hill, Ark. (Geological Survey). Made December 8, 1888, by St. Louis Sampling and Testing Works, at works:

DURATION OF TEST	*hours*	7½
Mean height of barometer	*inches of mercury*	....
" temperature of boiler room	*degrees, F.*	58.00
" temperature of outside air	*degrees, F.*	49.00
" condition of weather		Rainy.
" steam pressure above atmosphere, by guage	*lbs.*	70.00
" temperature of steam	*degrees, F.*	315.90
MEAN ABSOLUTE STEAM PRESSURE	*lbs.*	84.80
" height of water level	*inches*	6.56
MEAN PERCENTAGE OF WATER ENTRAINED IN STEAM	*per cent.*	3.00
" temperature of feed water	*degrees, F.*	64.80
Pounds of water apparently evaporated	*lbs.*	9342.00
Equivalent evaporation to dry steam from and at 212 degrees F.	*lbs.*	10,821.00
Equivalent evaporation per hour..1442.8 pounds,	*boiler horse power*	41.80
EQUIVALENT EVAPORATION PER HOUR PER SQUARE FOOT OF HEATING SURFACE	*lbs*	1.98
Weight of coal used 1700..plus coal equivalent of wood..13..	*lbs.*	1713.00

WEIGHT OF ASHES, CLINKERS AND COAL WHICH FELL THROUGH GRATE, 684 *lbs*........*Per cent. of waste*..	40.00
Percentage of unburned fuel which fell through grate.....*per cent*..	33.20
PERCENTAGE OF CLINKERS IN FUEL ....*per cent*..	0.00
Mean opening of damper (percentage of full opening)....*per cent*..	50.00
MEAN TEMPERATURE OF FLUE GASES...............*degrees, F*..	425.00
Mean pressure of draft in flue.................*inches of water*..	.06
MEAN THICKNESS OF FIRE ....*inches*..	5½
MEAN OPENING OF AIR INLETS above fire, per square foot of grate ....*square feet*..	.002
POUNDS OF COAL BURNED PER HOUR PER SQUARE FOOT OF GRATE.................................*lbs*..	10.15
POUNDS OF COAL BURNED PER HOUE PER SQUARE FOOT OF HEATING SURFACE.......................*lbs*..	313.00
MEAN SMOKE PRODUCTION, ON SCALE OF 10....................	½
MEAN COMPOSITION OF FLUE GASES, PER CENT., N............. O...............CO2..............CO.............	
EVAPORATION OF WATER FROM AND AT 212 DEGREES, F., PER POUND OF COAL ....*lbs*..	6.32
EAVPORATION OF WATER FROM AND AT 212 DEGREES, F., PER POUND OF COMBUSTIBLE..............*lbs*..	10.50

Fuel used: kind, Coal Hill, Arkansas............size, 2½ in. dia..........

Chemical composition of coal, ultimate:

Per cent., C. 78.60; H. 4.58; O. & N. 2.61; S. 4.55.

Chemical composition of coal, proximate:

Per cent., H_2O......Vol......F. C.....ash....

Calorific power of coal, B. T. U., per lb., calculated by Calorimeter..	12,500.00
Theoretical evaporative power from and at 212 degrees, F.........	12.94
Percentage of total calorific power utilized, or efficiency......	49.00

Slacks somewhat when first heated. Burns rather slowly, with thin, bright, smokeless flame, and requires some stirring. Stirring causes large amount of fine coal to fall through grate. Very little clinker. Ash poorly burned and fine.

ST. LOUIS SAMPLING AND TESTING WORKS,

1225 and 1227 Spruce Street, St. Louis.

Results of evaporative tests on No. III, Jenny Lind, Arkansas, coal. Made February 16, 1889, by St. Louis Sampling and Testing Works, at works:

DURATION OF TEST.................................*hours*..	8.00
Mean height of barometer.................*inches of mercury*..	....
" temperature of boiler room...................*degrees, F*..	63.00
" temperature of outside air....................*degrees, F*..	62.00
" condition of weather	Rainy.
" steam pressure above atmosphere, by gauge..... ..*pounds*..	74.60
" temperature of steam.........................*degrees, F*..	322.00

MEAN ABSOLUTE STEAM PRESSURE....................*pounds*..	92.00
" height of water level ....*inches*..	6½
MEAN PERCENTAGE OF WATER ENTRAINED IN STEAM....*per cent*..	0.30
" temperature of feed water.....................*degrees, F*..	164.00
Pounds of water apparently evaporated ....*pounds*..	11,000.00
Equivalent evaporation to dry steam from and at 212 degrees, F...............................*pounds*..	11,900.00
Equivalent evaporation per hour..1487 pounds, *boiler horse power*..	43.00
EQUIVALENT EVAPORATION PER HOUR PER SQUARE FOOT OF HEATING SURFACE.....................*pounds*..	2.00
Weight of coal used...1540...plus coal equivalent of wood..18 pounds..................................	1,558.00
WEIGHT OF ASHES, CLINKERS AND COAL WHICH FELL THROUGH GRATE ..*218 pounds. Per cent. of waste*..	14.00
Per centage of unburned fuel which fell through grate ....*per cent*..	7.20
PERCENTAGE OF CLINKERS IN FUEL...................*per cent*..	3.00
Mean opening of damper (percentage of full opening) ...*per cent*..	10.00
MEAN TEMPERATURE OF FLUE GASES................*degrees, F*..	490.00
Mean pressure of draft in flue..................*inches of water*..	0.10
MEAN THICKNESS OF FIRE ....*inches*..	9.50
MEAN OPENING OF AIR INLETS ABOVE FIRE, PER SQUARE FOOT OF GRATE.....................*square feet*..	0.00
POUNDS OF COAL BURNED PER HOUR PER SQ. FT. OF GRATE....*lbs*..	10.70
POUNDS OF COAL BURNED PER HOUR, PER SQUARE FOOT OF HEATING SURFACE..........................*lbs*..	.26
MEAN SMOKE PRODUCTION, ON SCALE OF 10	0.10
MEAN COMPOSITION OF FLUE GASES, PER CENT., N............... O......CO_2......CO	
EVAPORATION OF WATER FROM AND AT 212 DEGREES, F., PER POUND OF COAL.........................*lbs*..	7.64
EVAPORATION OF WATER FROM AND AT 212 DEGREES, F., PER POUND OF COMBUSTIBLE...............*lbs*..	9.55
Fuel used: kind, Jenny Lind, Ark., Coal...size dust to 3 in. diameter..	
Chemical composition of coal, ultimate: per cent., C., 79.48..H., 5.02..O. and N., 4.77..S., 2.11....	
Chemical Composition of coal, proximate: per cent., HO....Vol ...F. C....Ash....	
Calorific power of coal, B. T. U., per lb., calculated by calorimeter..	12,740.00
Theoretical evaporative power, from and at 212 degrees, F	13.20
PERCENTAGE OF TOTAL CALORIFIC POWER UTILIZED, EFFICIENCY..	58 per cent.

Ignites easily, burns with thin, bright and almost smokeless flame. Requires little stoking. Small amount of clinkers which gives no trouble. Ash fairly clean and somewhat fine.

The gist of the results concerning the evaporative powers of the coals tested is contained in the tables on p. 70, showing the evaporation of water from and at 212 degrees per pound of coal and per pound of combustible.

A study of these results shows that, per pound of coal, and with the class of boiler used, the Coal Hill coal yields the lowest results, the Huntington coal the highest, the Jenny Lind coal an intermediate amount, and that all of these Arkansas coals have a lower evaporative power than the standard or Pittsburg coal. Per pound of combustible, however, the conditions are reversed; the Coal Hill coal yields the highest results, the Huntington the lowest, and the Jenny Lind is again intermediate, while all of these give better results than the standard or Pittsburg coal. The explanation of this is seen in the tabulated descriptions of the tests on pages 73, 74, 76, 77 and lies in the difference in the amounts of ashes, clinker and coal which fell through the grates.

With the Coal Hill coal as much as 40 per cent. of the coal was thus wasted, with the Jenny Lind coal 14 per cent., and with the Huntington coal 10 3 per cent.; whereas, with the Pittsburg coal only 8.10 per cent. was lost. The results of the attrition tests given on p. — show the friable nature of the coals tested; but the screenings from the Coal Hill coal are less than from either of the others, and the large amount of the former coal wasted through the grate is due to the fact that this coal does not coke in the fire, as do the others, so that the fine coal does not stick together but falls through the grate and is wasted. To obtain anything like the full value of the coal a special form of grate is needed which will prevent this excessive loss through the bars.

The evaporative duties which may be expected with these coals under certain favorable conditions are given on p. 70, and, for comparison, they are tabulated below along with the duties of certain other competing coals in different furnaces. The conclusions which can be drawn from such comparison can be considered only as very rough approximations, and due

allowance must be made for the different types of boilers used and different modes of firing.

The figures are for pounds of water evaporated from and at 212 degrees F., and under atmospheric pressure.

COALS.	(1)	(2)	(3)	(4) MEIGS.		(5)
	Johnson.	Blake.	Potter.	Meigs Boiler.	Little Giant Boiler.	Babcock & Wilcox Boilers.
Pittsburg, Pa	8.20	......	8.5	8.78	6.74	10.20
Huntington, Ark	......	......	8.5	......	......	....
Jenny Lind, Ark		......	8.4	......	......	....
Coal Hill, Ark	......	......	7.0	......	......	....
Kansas coals	......	6.50	.....	......	......	....
Leavenworth, Kan	......	......	......	6.49	6.42	....
Indiana block	......	7.21	......	......	......	9.47
Cannelton, Ind	7.34	......	......	7.32	7.12	....
Run of mines, Ill	......	......	......	......	......	9.49
Staunton, Ill	......	......	......	......	......	5.09
Macallister, I. T	......	......	......	7.68	6.96	....
San Antonio, M Co. Tex	......	......	......	......	4.46	....

(1) Experiments on the Evaporative Power and other Properties of American Coals. Report to the Secretary of the Navy, 1844, by Walter R. Johnson.

(2) The Evaporative Power of Kansas Coals, by L. T. Blake. Sixth Biennial Report of Kansas State Board of Agriculture. The result given is approximately the average of an estimate from calorimetric tests of over 30 Kansas coals.

(3) Tests made for the Arkansas Geological Survey.

(4) Report on Fuel for the Army. By Quartermaster General Meigs, 1882.

(5) Evaporative Power of Bituminous Coals. By William Kent. Trans. Amer. Soc. Mech. Engrs. Vol., IV., 1883. These boilers were provided with a proper furnace setting for the combustion of bituminous coals.

Concerning the other Arkansas coals, all that can be said as to their steaming qualities is what can be deduced from their analyses, from considerations of their location and from their behavior as reported by consumers. On the basis of their composition and location, the workable coals cited in the table of analyses would thus group themselves somewhat as follows with reference to their steaming capabilities:

Similar to Huntington Coal.	*Similar to Jenny Lind Coal.*	*Similar to Coal Hill Coal.*
2. Page's coal.	12. Bocquin & Reutzel coal.	24. Allister coal.
3. Baxley's coal.	14. Carlan coal.	
4. Hackett City coal.	15. Moomaw's coal.	
5. Pickartz's coal.	17. Petty's coal.	
7. Claiborne's coal.	18. Philpott coal.	
9. McConnel's coal.	19. Watt's coal.	
10. Greenwood coal.	20. Felker coal.	
13. Gwyn's coal.		

The Ouita coal (21) and the Eureka coal (22) are not considered to be good steaming coals. They are not so easily ignited nor so free burning as the others; but, with properly arranged drafts and handled by a man used to firing anthracites or similar coals there is little doubt about these coals yielding good results. Along with these, Harkreader's (26) and Shinn's (27) coals are properly classed.

With a view to throwing additional light upon the subject of the steaming qualities of Arkansas coals, various classes of consumers were interrogated and considerable correspondence was entered into. The results have not proved as generally valuable as was hoped for, the replies not being in sufficient number for obtaining an expression of the average opinion. A few are introduced here, however, which furnish at least some valuable hints as to the experience of the consumers.

The Little Rock Ice Company (*) reports, with reference chiefly to Coal Hill or Allister coal, but also from experience with Jenny Lind coal, as applied to stationary boilers, that an intensely hot fire is produced. Can get more work out of Arkansas coals per ton than out of any other coal ever used. Gases have no decided effect upon flues excepting where a leak exists; corrosion is then rapid. Effect on grate bars is severe even when fired lightly, and with heavy firing will burn out grate bars in a short time. Very little ash is made to speak of. Coal is found to slack or disintegrate a good deal in transportation and on exposure to the weather. But, "all things considered," the two coals are regarded to be as good steaming coals "as anybody wants." He prefers the Coal Hill coals to coals from Tennessee, Kentucky or Alabama. The Spadra (Eureka) coal is considered "utterly worthless for steam purposes."

The Master Mechanic of the St. Louis and San Francisco Railroad, Mr. M. Kearney, writes that the few Arkansas coals which have been tried will not do for blacksmithing purposes. Some coal received from the Little Rock Railway (pre-

*Private communication of Mr. L. W. Cherry, President and Treasurer.

sumably Coal Hill or Allister coal) was as good as any they had ever used and were able to make more miles to the ton of coal than with any other coal.

The Master Mechanic of the Little Rock and Fort Smith Railway, Mr. F. Hufsmith (now Superintendent of Transportation of the St. Louis, Arkansas and Texas Railway), writes that Coal Hill (or Allister) coal was used on the Fort Smith and Little Rock road for steaming purposes with very good results. Had no bad effects on either flues or fire boxes, and locomotive grate bars, properly constructed, would last from twelve to fourteen months. The amount of ash and clinker was about 23 per cent., "as near as I can remember." Two tons of Arkansas coal would run an engine and full train as far as three tons of Illinois coal.

This coal is now used on the Fort Smith and Little Rock and on the Iron Mountain roads. Engineers criticise it as being a good coal for steam but makes a good deal of clinker and is rough on the grates and causes a peculiar incrustation on the flue plate.

Arkansas Industrial University—Used slack coal from Hackett City with much satisfaction, in stationary boilers. It makes more steam but burns quicker than Kansas coals and does not clinker like the latter, which stuck to the grates and injured the bars. It kindles readily, no excess of sulphur is noticed, and leaves a light cinder.

*The Van Buren Ice and Coal Company** finds the Coal Hill or Allister coal to be the best steaming coal they have used. It clinkers considerably and will burn out the grates if they are not well cleaned and cared for. No injurious effects from sulphur was noticed. A great deal of slack is lost through the grates, causing a large amount of waste, which, together with the ash, reaches as much as six to eight barrowfulls to the ton.

The Hackett City coal is found not to equal the Coal Hill coal for steaming purposes but is quicker to ignite and burns more freely. It makes a loose pulverulent ash, does not burn out grates and is easily taken care of. About two barrows of ashes to the ton are formed.

Huntington coal burns in about the same manner as the Hackett City coal, but is softer and makes more slack.

Jenny Lind coal is found to be a better steaming coal than the Hackett City coal, but resembles it in particulars. It makes a loose ash and contains little sulphur.

D. R. Wing & Co., founders and machinists of Little Rock, report as follows:

"We use Arkansas coals for our steam boiler and heating purposes only. We have used coal from every mine in the State of any commercial importance. The mines differ to a great extent in the nature of their combustion.

"With but few faults, and many virtues, the coals of Arkansas should take first rank for their economic heat generating qualities. Being readily kindled, with freedom from smoke, and a low percentage of ash and clinker, they are justly entitled to stand at the head of the class with the best of the world."

Home Water Company of Little Rock—Mr. Zeb Ward, Jr., the Superintendent, writes that he considers the coal from the Coal Hill mines the best on the market

*From an interview with Mr. W. H. Hayman, chief engineer.

for steam purposes. It evaporates 7.91 pounds of water per pound of coal, and forms about 18 per cent. of clinker and ash. The coal is a little hard on grates, but makes very little soot and is free from smoke. It does not stand storage well and goes to slack when exposed any length of time. It stands the transportation to Little Rock well, but will not bear much handling.

City Electric Light Company, of Little Rock.—Mr. W. H. Hinkle, the engineer, writes that Coal Hill (Horsehead) coal makes a very intense heat on the grate bars and needs at least a fourth more grate surface than any other coal ever used, and has to be fired very light. He had the best results from Stiewel & Co.'s coal (he thinks the Eureka coal), using nut and slack. It makes a clinker but burns out the grate bars very little. To produce the same evaporation with Illinois coal as with the best Arkansas coals takes at least a fourth as much coal more. Kentucky coal, he states, is similarly lower in evaporating power and makes a great deal of soot in the flues.

For the Manufacture of Iron and for Metallurgical Purposes coal is chiefly used after being converted into coke, though it is also used to a limited extent in the raw state. Coal that can be thus directly used must, however, be strong and not swell nor disintegrate so as to choke the furnace, should be capable of producing a high heat and should not contain a large amount of sulphur or phosphorus. The last constituents are especially objectionable in a coal to be used for forge purposes. But a coking coal is, after all, by far the most valuable for metallurgical purposes. Coking also permits the saving of all the fine slack which is produced in the mining and handling of a soft coal. With anthracite and other non-coking coals a great part of this goes to waste,* while with a coking coal it is all converted into a merchantable product.

Coke is the fixed carbon of a coal, a fused and porous product produced by the distillation of the gaseous constituents. For metallurgical use it should be firm, tough and bright with a sonorous ring, and should contain not over 1 per cent. of sulphur. For blast furnace use a dense coke is objectionable and the best is the one with the largest cell structure and hardest cell wall.† A high percentage of volatile hydrocarbon is, as a rule, necessary for a good coking coal. Thus Connellsville coal has about 30 per cent. and a

*For notice of modern methods of utilizing coal dust, see Chap. VI.

†See paper by John Fulton. Appendix, Report G., Second Geol. Survey of Pennsylvania.

fuel ratio of about 2. Some coals with a high percentage of volatile matter do not make good coke, however. And again others, with a comparatively low percentage, make excellent coke. The Flat Top or Pocahontas coal of Virginia is such a coal. It has only 18 or 19 per cent. of volatile hydrocarbons and a fuel ratio of about 4, and is classed in the trade as a semi-bituminous coal. The coke is firm and ringing, though duller than the Connellsville coke. A coal, cited in the reference list of the table of analyses, from Charleroi, France, has only about $15\frac{1}{2}$ per cent. of volatile matter and a fuel ratio of over 5,* and is yet reported to produce a well formed coke. Cokes from such coals are, however, generally much more dense than those from more bituminous coals, and, hence, inferior for blast furnace use. Thus, other factors, besides the proportional amounts of fixed carbon and volatile matter in a coal, affect its coking capabilities. Just what these are, is, to a great extent, a mooted question. The fusibility of the carbon, the amount of disposable hydrogen, the tenacity with which the gaseous constituents are held, all affect the result. Further, coal which is mined near the outcrop and has been subjected to the influence of the weather, loses its capacity for coking. The process of manufacture should, however, be adapted to the character of the coal, as it has an important, though secondary, influence upon the physical character, uniformity of quality and dryness of a coke. Coals of inferior grade are made to produce good coke in Europe by using coke ovens in which the heat of the gases is applied externally to the coke chamber, but the coal is generally first carefully crushed and washed. Further, the depth of the charge and length of heating have an important bearing.

The low percentage of volatile hydrocarbons in Arkansas coals does not offer an encouraging prospect for the production of merchantable coke. All of the samples collected for analysis were subjected to crucible tests in the laboratory, and the results of these tests are shown in the table on page 43.

*This means a less bituminous coal than either that from Huntington or Hackett City.

Various tests on a working scale have also been made by both producers and consumers of coal. The results of some of these are given below.

During July and August, 1888, the Kansas & Texas Coal Company had a test made, in a beehive oven, of the coking qualities of slack coal from their Huntington and Hackett City mines. It was conducted by Mr. James Rae, who had previously been in charge of the coking plant at the McAllister mines in Indian Territory.

Of the Huntington coal three tests were made in all. The oven was first heated to a white heat. All charges were of slack coal, washed free of slate and dried. The depth of the charge was fifteen inches in each trial. With enough draught to consume the gases and to remove smoke, combustion lasted four hours and would then have died out. After this four hour combustion, a crust of half made coke, about three inches thick, was formed over the top. Beneath this the coal had not changed in appearance, though all flame had ceased and all the volatile matter was apparently distilled off. On admission of more air and with increased draught, the coke and other material was gradually consumed, with no more coking. In the third test about a cord of wood was burnt on top of the charge. with a view to increasing the temperature, but no improvement was noticed.

The Hackett City coal was similarly treated, being charged into a white hot oven, but left there seventeen hours. No coke at all was formed. The coal was burnt a little on top, but the remainder underwent, apparently, no change. The depth of charge was here about 15 inches also.

D. R. Wing & Co., founders and machinists of Little Rock, state that they have used the coal from McAllister, Indian Territory, and also Stiewel & Co.'s and the Ouita Coal Co.'s coals from Coal Hill. in the raw state, for forging. The McAllister coal gave the best results. Coal Hill coal was found to be too soft, to contain too much sulphur and slate and would not give sufficient heat. No attempt had been made to coke Arkansas coals and no native coke had been tried.

The Thomas Cotton Press Co. of Little Rock state that they tried one lot of Coal Hill (or Allister) coal raw in the furnace, and though it answered fairly well, coke proved more economical. They use Coal Hill slack coal in the blacksmith shop.

The Vulcan Foundry and Machine Shop of Fort Smith report the following:

"I use the coal from most all of the mines around here, but I think the Jenny Lind is the best. I made my own coke for several years for iron smelting, but found that the coal swelled too much, making the coke too light, and unfit therefore to hold up the bed. The coke is freer from sulphur than any I have used. I have used both Chattanooga and Connelsville coke. ..nother trouble was that I could not use slack coal in making the coke. The Campbell mine near Central City yields a coal which melts better by heating in the forge, but it has considerable sulphur. All the coal burns well, but is too light for heavy forging. It burns to ashes with very few clinkers."

The Ketchum Iron Works of Fort Smith have experimented with coke from a

"Scotch" pit, about eight miles beyond Central City (probably Watt's slope), but found it to contain too much sulphur, with the result of making the iron "hard."

Another Fort Smith foundry experimented with Jenny Lind coal from Petty's slope for the production of coke but the product was too light for furnace use.

At Greenwood during the winter of 1889 a rough test was made of the coal from the shaft at that place. A pile of lump and slack coal was built about 20 feet long, by 8 feet wide, by 5 feet high. This was covered with earth excepting over three flue openings. The pile was ignited and after smoke had ceased coming off, all openings were closed and it was allowed to cool for some seven days from the time of firing. The product was a dark, dense mass, dull, with no metallic ring, and a fine cell structure, more comparable with gas retort coke than with merchantable oven coke.

One of the samples of coal sent to St. Louis by the Survey gave promise of being suitable for the production of coke and was therefore tested. The results are given on page 71, and what is there stated concerning the Jenny Lind coal will probably apply to all Arkansas coals, judging from the low percentage of volatile matter which characterizes all, and from the results of other tests of which we have record.

For Domestic Purposes,

Coal is used in open grates, in closed stoves with ordinary fire bowl and flat grate, or with basket grates in small furnaces for hot air heating, and in cooking stoves. In all of these the best coal is one which is capable of sustaining a mild and steady combustion and of remaining ignited at a low temperature, with a comparatively feeble draught. A coal burning with a smoky flame is objectionable as producing much soot and dirt, especially for open grates or for cooking purposes. For self-feeding stoves or for "base-burners" a dry, non-coking coal is necessary. A very free and fiercely burning coal is not desirable, particularly in stoves, as the temperature cannot be easily regulated. A sulphurous coal is also bad, producing stifling gases with a defective draught, and corroding grates and fire bowls. The difficulty from clinkering is not so great in domestic uses, as the temperature is not generally high enough to fuse the ash. A stony, hard ash, which will not pass between the grate bars is bad, and light, pulverulent ash is best.

Arkansas coals are all suitable for domestic uses, but some much more so than others. They are all more or less free burning, kindle easily and burn with a slight draught. Those of the western part of the State, the Hackett City and Huntington coals, will swell and coke somewhat in the fire, but not objectionably so. They leave a loose, pulverulent ash, and do not burn out the grates. Jenny Lind coal is similar in its burning and is a favorite domestic coal at Fort Smith.

Coal Hill (or Allister) coal is not esteemed as a domestic fuel. When combustion is once fairly started it burns with an astonishing vigor, producing, even with open grates, an objectionably intense heat. This fierce combustion accounts for its steaming capacity. It is due in part to the easy disengagement of volatile hydrocarbons and also to the peculiar intumescence which this coal exhibits and which is mentioned in the description of the Coal Hill mines on p. 31. This intumescence causes a swelling and loosening of the fire, so that the air passes freely through it and is brought into immediate contact with the coal. With this intense heat the sulphur in the coal becomes very active, and as a result grates and stoves are corroded. Some cinder or loose clinker is also formed.

The Philpott and Felker coals have both a much better reputation as domestic coals than has the Coal Hill coal.

Among the best of Arkansas coals for domestic purposes is, however, the Ouita coal, mined in Pope county. In fact, it seems to combine all the chief requirements of such a coal. It is a reasonably hard coal and stands shipment fairly well. It is easily kindled, for a dry coal, and burns steadily and slowly with a regular and moderate heat in an open grate. With a slight increase of draught, however, the intensity of the heat can be quickly raised. The coal does not coke nor swell but gradually burns away, leaving a loose, reddish ash. Once started, a fire of this coal requires no attention, and a few smouldering coals in a grate will remain ignited twenty-four hours or more. It makes no smoke nor clinker and does not burn out grates. It is pre-eminently a coal for self-feeding stoves or base burners and for kitchen use.

The Eureka coal of Johnson county is similar to the Ouita coals in being free burning and not swelling. It is said to form a fusible clinker, however. Still it is an excellent coal for self-feeding stoves and for other domestic uses.

The coals from the Shinn slope and in Harkreader's well are inferred, from their composition and physical characters, to have properties similar to those of the Ouita and Eureka mines.

For the Production of Illuminating Gas

A coal should contain, at least, between 30 and 40 per cent. of volatile hydrocarbons. The small amount of gaseous matter in Arkansas coals at once removes them from the class of gas coals. They could, of course, be made to produce gas, but it would be a small quantity per ton of coal, and, with present market prices for good gas coals in home markets, there is no prospect of Aarkasas coals being put to such use. They have been tested, however, at the gas works in Little Rock and Fort Smith, and the following results are communicated:

The Little Rock Electric Light Company tested Coal Hill coal but found it to contain too much sulphur and made no coke. Felker coal was tried recently but the gas was deficient in illuminating power. The coke was too light and soft. They use Youghiogheny coal entirely.

The Fort Smith Gas Works have tried Hackett City and Jenny Lind coals but they gave a poor illuminating gas, and only yielded 3¼ to 3¾ cubic feet io the pound. They obtain their coal for gas purposes from Pittsburgh, Kansas.

CHAPTER VI.

THE UTILIZATION OF COAL DUST OR SLACK.

With the ordinary process of mining and the present methods of cleaning the coal for market much waste results, with the softer coals, in the formation of pulverized coal, technically called coal slack or screenings, or, with anthracite, "culm." With the adoption of any process of crushing the coal in preparing it for market, the amount of this coal dust would naturally be increased. The utilization of this product by coking, as with bituminous coals, would, of course, furnish the easiest solution of the problem, but, for those coals which will not coke, this avenue is closed. By the use of improved forms of screens much of this slack might be saved by not being made, while for the extensive use of slack as a fuel, improvement in the method of preparation is necessary for the purpose of separating the coal dust proper from the slate and other refuse.

Generally speaking, such coal dust is utilized in three different ways: First, directly, by special furnace arrangements such as in the form of grate, in the manner of feeding the fuel or in regulating the draft; second, by converting the dust, mixed with some other material, into a solid fuel; third, as an accessory in the manufacture of other materials.

A description of these processes will not be attempted here. Just which one could be applied with most practical effect to Arkansas coals can be determined only by actual experiment With the enlargement of coal mining operations in the State, it would well pay the larger operators to investigate this subject. Suffice it here to call attention to the principal lines of inquiry.

The first method, that of using the fine coal directly, by special furnace arrangements, has proved a practical success

in the case of anthracite coal in Pennsylvania, when mixed with certain proportions of "buckwheat" coal, which latter is ordinarily the smallest marketable size. ("Buckwheat" coal passes through a ½-inch mesh). The Wooten locomotive fire box is a well-known form of "culm" or "slack" burner. The Philadelphia and Reading railway has made a large saving through its use. The grate area is as much as 64 square feet. The combustion is slow and the fuel remains quiet in the box, little smoke or sparks being ejected from the stack. The coal consumption is only about 16 pounds per hour to the square foot of grate, against 40 to 60 pounds in ordinary locomotive firing. For stationary boilers, and also for domestic uses, special forms of grates have been designed, such as the Dockash and the McClave grates, manufactured in Scranton, Pa. These are especially constructed to prevent fine fuel from falling through into the ash pit. With this they combine a shaking movement (with no increase of size of opening), which will break up a coking fire, remove fine ashes, and cut off and remove clinkers instantly. Where deemed advisable, artificial draft is produced either by a fan or blower or by a steam jet; the steam jet acts as an exhaust in the stack, or generally is introduced, mixed with air, into the closed ash pit beneath the grate bars. An addition of a small proportion of bituminous coal dust improves the fuel. The successful utilization of waste coal through special furnace contrivances is currently acknowledged to be one of the chief causes of Scranton's rapid growth.

Another and a promising method of utilizing coal dust is by dispensing with grates entirely and by introducing the fuel into the furnace mixed with air in a blast. The Crampton puddling furnace is a well known application of this principle. A system of burning powdered fuel, patented by Messrs. Whelpley and Storer, was tested in 1876 by the United States Government;* though the conclusion was reached that the coal could not be burned fast enough, it was by no means

*See Annual Report of the Chief of the United States Bureau of Steam Engineering for 1876.

finally decided. A device known as the Stephenson apparatus has been used with flattering results in England.*

What is termed the McAuley process of burning pulverized fuel is claimed to yield excellent results in puddling furnaces. Any originality in his method lies in the special device for mixing the coal dust with the air blast.†

Within the past year the Cyclone Pulverizing company of New York has taken up the construction of furnaces for the combustion of pulverized coal, and excellent results, it is understood, have been reached with furnaces in Newark, New Jersey. Mr. Erastus Wiman, of New York, is prominently identified with this enterprise.

One of the most promising uses of slack or pulverized coal is in the manufacture of water-gas or fuel-gas by the Strong, Lowe, Loomis or other process. The many considerations which go to recommend the production and use of this gaseous fuel lead one to believe that it will be widely introduced in the near future.‡

The second general method of making use of coal dust by converting it, by admixture with other substances, has not generally proved a commercial success. One process consists in mixing the non-coking coal slack with a proportion of a coking coal dust (one-fourth or one-third, according to the coking properties of the coal) and simply coking the mixture. The grains of non-coking coal remain unchanged, and the bituminous coal simply solders these together. Special grinding and preparation is necessary to produce a firmly coherent coke of this kind, and at the same time to economize coking

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*See the Combustion of Coal. By W. M. Barr, p. 239. Indianapolis: Yohn Bros., 1879.

†See *Science* for December 28th, 1888.

‡For information concerning these processes the reader is referred to: Trans. Amer. Inst. Mining Engineers, Vol. VIII, p. 289; Vol. XI, p. 301; Proc. Inst. Civil Engineers, Vol. LXXXIV, p. 2; Van Nostrand's Eng. Magazine, Vol. XXVI, p. 319, Vol. XXVIII, p. 7; Eng. and Mining Journal, Vol. XLV, p. 196; Scientific Amer. Supplement, Nos. 53, 114, 216, 303, 311, 398; The Combustion of Coal. By W. M. Barr.

coal.* The socalled artificial fuels generally consist of coal dust, mixed with some cementing material to make the particles cohere, and then compressed into lumps. Clay, silicate of soda, pitch and a mixture of pitch and bituminous slack have all been used. The last named is adopted in the Loiseau process which produced a very excellent fuel. The coal dust used at the Loiseau works at Port Richmond (Philadelphia) was, however, of a cleaner nature than what is ordinarily available at mines; it came from the screenings from the large coal yards.†

As an instance of the employment of coal dust directly in the manufacture of other materials can be cited its use in brick making. There, kneaded with the clay, it has the effect of both saving a portion of the fuel and of diminishing the time of burning. In 100,000 bricks, some seventy-five bushels of anthracite coal dust will save about fourteen cords of wood in the burning.

This whole subject deserves attention. If such an inert substance as anthracite "culm" can be profitably burnt, there is no reason, as far as the material is concerned, why the slack

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*See Percy's Metallurgy. Vol. Fuel, p. 461.

Crucible tests were made in the laboratory of the Survey by the chemist, Dr. R. N. Brackett, with two separate lots of Ouita (Pope county) coal mixed respectively with one-fourth and one-third parts by weight of Connellsville coal. In the former the Ouita coal was ground coarsely, the particles varying from fine dust size to about one-quarter of an inch in diameter; the Connellsville coal was in the condition of a tolerably fine powder. The product was a granular, dense and reasonably coherent coke. In the latter test both coals were ground to powder. The product was a dense, tenaceous coke. Both lots were heated in an ordinary assay crucible in a Hessian furnace for about half an hour. Such a product might well be utilized for similar purposes, as is gas house coke.

A brief description of a method employed in Wales to utilize waste heaps of fine coal dust by coking with bituminous coal and pitch, by Mr. Franklin Platt, will be found in Report L of the Second Geological Survey of Pennsylvania. Further results of tests made by Mr. Platt in Pennsylvania are contained in Report MM. of the same survey on pp. 382–397.

†See Trans. Amer. Inst. Mining Engineers, Vol. III, p. 13; Vol. VI, p. 214; Vol. VIII, p. 277, p. 314, p. 320; Vol. IX, p. 294.

Van Nostrand's Engineering Magazine, Vol. 9, p. 64, p. 81; Vol. 23, p. 41.

Scientific American Supplement, July 28, 1887.

of Arkansas coals can not be similarly utilized. The incipient and partial coking which some of these coals exhibit will only enhance their value for this purpose. It especially should be carefully considered with reference to those coals which slack so readily on exposure or after long heating. The present system of sending every consumer his *pro rata* of slack along with the lump coal is damaging to the trade. And, at the mines, the amount of material that is mined and handled, only to be thrown away as slack, represents just so money wasted. With large consumers this matter deserves scientific and exhaustive experimentation. Hap-hazard, partial tests will yield no satisfactory results. If the raw slack can be sold, through the use of special means of combustion, at a price assuring a reasonable profit over the cost of shipping, it becomes a marketable product. Similarly, if the manufactured fuel can be sold at a price yielding a reasonable profit over the cost of manufacture and transportation, it must prove a commercial success. The cost of manufacture must necessarily be below the cost of mining and preparing the large coal for the market.

APPENDIX A.

THE PREPARATION OF BERNICE ANTHRACITE COAL.*

By CLARENCE R. CLAGHORN, M. E., Birmingham, Ala., late Mining Engineer State Line and Sullivan Railroad Company, Bernice, Pa.

Bernice coal while being a pure anthracite† has a distinctly bituminous fracture and is comparatively soft and friable. Since it comes in competition in the various markets to which it is shipped, principally throughout New York State, the West and in Baltimore and Washington, with the other anthracite coals, it must be prepared in the usual commercial sizes. Not being particularly adapted for use in locomotives, nor strong enough to bear a burden in an iron furnace, there is very little demand for it in sizes larger than "broken," so that these sizes must be broken down to smaller sizes, thereby making the amount of dirt or "culm" considerably greater than would be were the larger sizes in active demand. Owing to its soft, friable nature and bituminous fracture, it requires a much more careful handling and a different treatment in preparation than do the other anthracite coals which are harder, and have a conchoidal fracture.

*Bernice coal, as is seen by its dercription, has, in its physical characteristics, much in common with Arkansas coals. The details of its preparation for market, can, it is thought, be applied to these coals without much modification, and hence this description of the methods in use at Bernice amounts, practically, to a description of methods recommended for Arkansas coals. A. W.

†A late analysis is that of Prof. Hayes, of Ontario School of Chemistry and Pharmacy, Toronto, Ont., Made February 10, 1888, and showing:

Fixed carbon	85.73 per cent.
Volatile matter	6.56 per cent.
Ash	5.90 per cent.
Moisture	1.81 per cent.
	100.00

In the preparation of any anthracite coal there are several main points to be considered. Anthracite coal, as it comes from the mines, is is an intimate mixture of pieces of various sizes, from the largest "lump" to the finest dirt or "culm," mixed with more or less slate and "bone." In this form it makes an undesirable fuel, so that to render it acceptable to the consumer, both for steam and domestic use, it must be subjected to a treatment which has for its objects the reduction of the larger pieces to suitable sizes, the separation of the various sizes from each other, and the removal, as far as possible, of the impurities, such as slate and bony coal. The machinery which it is necessary to employ in this treatment must combine a maximum of efficiency with a minimum of waste and expense. Under the head of efficiency must be considered also the proportion of the various sizes made; since some sizes are in much greater demand than are others and hence command a correspondingly higher price. In treating a soft, friable coal it would be natural to expect that a greater proportion of the smaller and undesirable sizes, and of "waste" would be made, than if the same machinery were operating on a harder and stronger coal; but if this machinery can be so changed as to decrease this proportion of the undesirable sizes, and to correspondingly increase those more in demand, greater efficiency would be obtained, provided other conditions remained the same. This difference in structure and hardness should always be borne in mind when comparing records of breakers working on different coals, and also the fact that the mesh of the screens used throughout the anthracite regions varies widely within certain limits, and in consequence of the size of the different coals and the proportion made varies considerably.* With these ends

*In general the sizes of coal may be said to be as follows:

Lump	over bars 7 in. to 9 in. apart.	
Steamboat	over bars 3½ in. to 5 in.	through bars 7 in. to 9 in. apart.
Broken	over mesh 2⅜ in. to 2⅞ in.	through mesh 3¼ in. to 4½ in.
Egg	over mesh 1¾ in. to 2¼ in.	through mesh 2⅜ in. to 2⅞ in.
Stove	over mesh 1 in. to 1¼ in.	through mesh 1¾ in. to 2¼ in.
Nut	over mesh ⅛ in. to ¾ in.	through mesh 1 in. to 1¼ in.
Pea	over mesh ⅜ in. to ½ in.	through mesh ⅝ in. to ⅞ in.
Dirt		through mesh ⅜ in. to ½ in.

in view a plant was erected at Bernice to properly screen and prepare the coal on a somewhat new principle, and upon comparing the records made by this breaker with those of the breakers operating on similar coals, such as are found in the Shamokin and Lykens Valley districts, the results were found to be eminently satisfactory.

The process of treating this soft Bernice coal differs from the usual method of preparing anthracite only in the system used in crushing. The coal coming from the mines, being a mixture of large and small pieces, is dumped upon the "dump" bars as is the custom elsewhere. These bars are two inches apart and are set at an angle of 30 degrees. The pieces of coal 2 inches and less in diameter fall through and are conveyed, in inclined chutes, directly to the separating screen. All pieces of coal larger in diameter than 2 inches pass over these bars and fall upon a large perforated cast iron table, circular in shape, revolving horizontally about its center on a vertical shaft. This table is 9 feet in diameter, and one and three-fourths inches thick. It is made of quadrants bolted together through flanges by inch bolts, the whole being held to the shaft by an iron band shrunk around a hub on the table, and by seats and key. This table around its circumference bears upon cast iron rollers set on timbers. The vertical shaft is 5 inches in diameter and receives its motion from an overhead gear wheel and worm. This table in revolving carries the coal which falls upon it under the crusher proper, locally known as the "monkey," which consists of a heavy cast iron frame 32 inches long, 16 inches wide, and 3 inches thick, in which are bolted 32 steel teeth in four rows, four inches apart from center to center; the teeth in each row being also 4 inches apart. Cast on this frame, on each end, and faced with brasses, are two bearings, each 13 inches long, and 4 inches wide. This frame is set in guides over the table as is shown in the figures, the guides admitting of a vertical motion imparted by two eccentrics and rods from a horizontal shaft overhead, which shaft, by means of a worm and gear wheel, imparts motion to the table. These eccentrics are set for a 7 inch stroke, and in

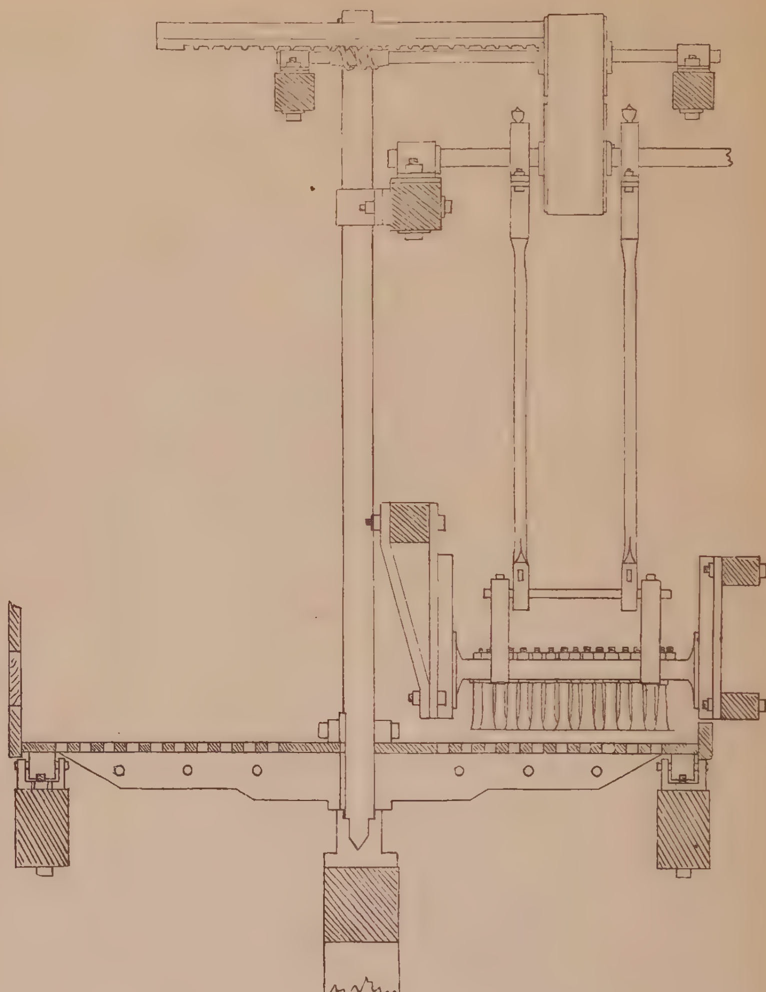


Fig. 1.
FRONT VIEW
OF
COAL CRUSHER.

In use at the mines of the State Line and Sullivan R.R. Co. Bernice, Pa.

Scale 1 in. = 30 in.

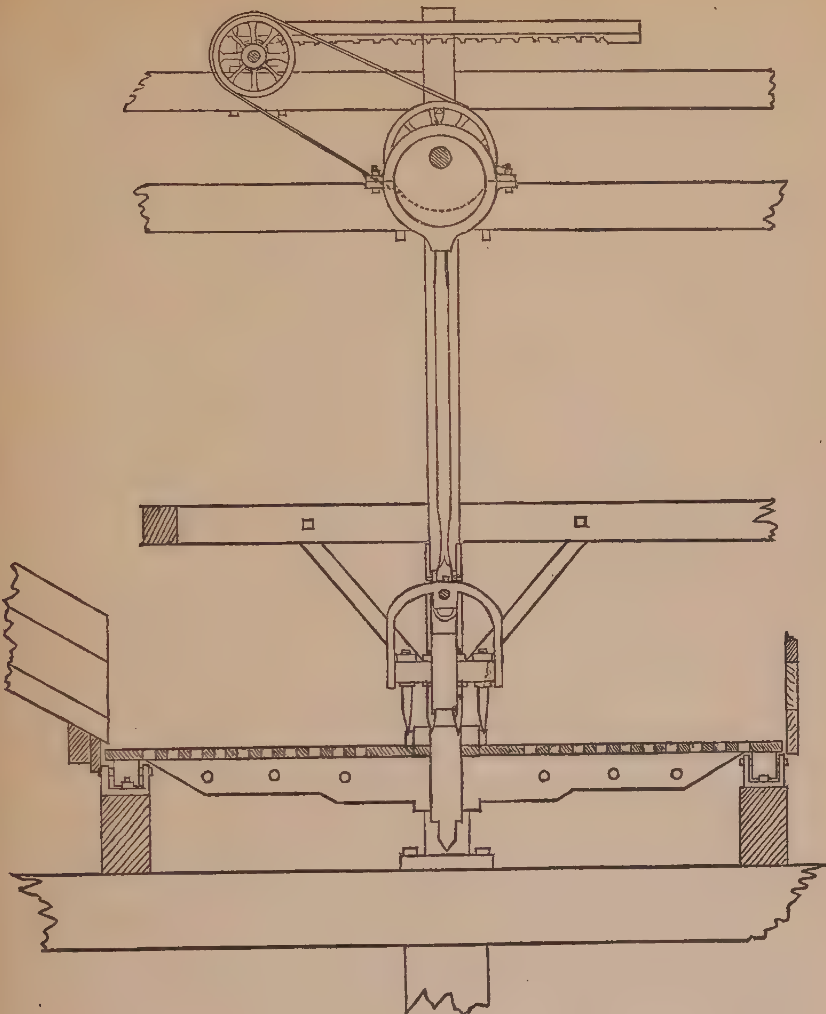


Fig. 2.
SIDE VIEW
OF
COAL CRUSHER.

In use at the mines of the State Line and Sullivan R.R. Co. Bernice, Pa.

Scale: 1 in. = 30 in.

consequence, at each revolution of the shaft, the "monkey" makes one upward and one downward stroke of 7 inches. The teeth are made of ordinary tool steel, $12\frac{1}{2}$ inches long, flattened out at one end to a chisel edge, the other end having a shoulder and thread and nut by which they are bolted solidly to the "monkey" frame. These teeth are easily removed, which is done from time to time for the purpose of sharpening them. The coal falling upon the table from the dump bars is carried under the money and is struck by it, the teeth *splitting* the coal into smaller pieces, and by the same motion of the table the coal is carried around, away from the crusher, where a bar, placed at an angle across the table, scrapes the coal off into an inclined chute by which it is passed to the main separating screen, there joining the small coal which passed through the dump bars above.

The speed of the table relative to that of the crusher, the shape of the teeth and the distance of the teeth from the table when at the end of the downward stroke, are elements bearing upon the proportion of the various sizes of coal made and can be adjusted to suit special conditions. For instance, should the demand for the larger sizes such as "egg" and "broken" be great, the "monkey" is raised, or the speed of the table relative to that of the crusher is increased and vice versa. Under ordinary circumstances, and with the usual demand, the teeth strike within 2 inches of the table, the table makes one revolution in $1\frac{1}{4}$ minutes, and the "monkey" makes 150 strokes per minute.

In many breakers, particularly in those erected in recent years, the screening is performed in a number of short screens instead of in one long screen, the classification of sizes being more perfect and the proportion of screen waste lessened.

How this principle would effect the Bernice coal it is difficult to say, as no experiments have been carried on with this end in view, but in all probability it would be as much if not more successful for Bernice coal than for a harder coal. At present all the classifying is performed in one screen 24 feet long, 5 feet 7 inches in diameter, set at a pitch of 1 foot in 10

feet, and, under ordinary circumstances, making 12 revolutions per minute, with a jacket 8 feet long, covering the upper end in which the pea is separated from the buckwheat and dirt. The separation is nearly perfect, the coal always giving excellent satisfaction. From this screen, as is usual, the coal falls into appropriate inclined chutes, while traversing which it is picked free of slate by hand, no machine as yet having been invented to supersede successfully this hand picking. By these chutes the coal is conveyed to pockets from which it is loaded, by gates over lip screens (which take out the dirt made in pockets and chutes) into the railroad cars for shipment.

The capacity of the crushing apparatus at Bernice is considerably in excess of the screening capacity. At present the breaker is capable of properly handling about 450 tons per day, but by adding another screen to the plant and dividing the coal between the two, the output could be increased one-half more. Such a breaker, with all its appurtenances complete, with the many improvements which experience always suggests, should be erected for $20,000, and it should handle coal at a cost of seven cents per ton on a regular output, say, 400 tons, working on similar coals and under like conditions.

In comparing the records made at the Bernice breaker, we must use records of breakers running on coals bearing a character similar to that of Bernice coal. It would be manifestly unfair to compare them with records of breakers treating the very hard Lehigh and Schuylkill coals, which have a different fracture, are much stronger, and stand much handling without a corresponding amount of waste. Coals to be used for comparison are found in the northern coal field, and in the western end of the southern field, particularly where the Lykens valley beds are mined.

Mr. Holden Chester, General Superintendent of the Lykens Valley Coal company, says:*

"The loss in the amount taken out, especially in soft or free burning coals, is about 38 per cent.; one-half or 19 per cent. of this is made in the mines by the explosives used; the

*Geol. Survey of Pa., Report A2, p. 120.

other half, or 19 per cent. is made in breaking and preparing the coal into domestic sizes.

"This result can only be attained by the use of the best machinery, which we too often neglect and allow to become dull, thus increasing the waste very much.

"But we too often lose sight of the other half of the waste brought from the mines, principally the fruits of the injudicious use of explosives by incompetent miners; and especially is this the case with the soft or free burning anthracite coals."

Col. D. P. Brown, General Manager of the Philadelphia Coal company, in making some experiments at Lost Creek colliery on *hard* white ash coals determined* that:

Breaking and screening by hand, wasted	6.28 per cent
Breaking by hand and screening through circular screens, wasted	10.28 per cent
Breaking through rollers and screening in present way, wasted	15.27 per cent

With another test† made at a colliery in the Shenandoah region, working the Mammoth bed and "furnishing a fine hard coal as their product" the amount of waste made by the breaker in breaking down 700 lbs. steamer coal through two sets of rolls, with good sharp teeth and chilled points, was 20 per cent. through a three-eighths inch screen. Still another test made at the same colliery about two years previous, using monkey rolls with chilled teeth and egg coal gave 25½ per cent. as the waste over a three-eighths inch screen. Thus it is safe to assume that Col. Brown's estimate of 15.27 per cent. as the waste of breaking and screening (4 per cent.) is well within the limits of accuracy for the harder Schuylkill coals.

Mr. Franklin Platt, in quite an exhaustive report on Coal Waste,‡ for the Second Geological Survey of Pennsylvania, gives the following general average of waste for all kinds of coals from the Wyoming Valley, which are mostly hard bright coals with a conchoidal fracture:

*Geol. Survey of Pa., Report A2, p. 51.

†Geol. Survey of Pa., Report A2, p. 52.

‡Report A2.

		Loss.	
1.	Diamond Breaker—Baltimore Vein, Improved Standard steel tooth crushers	11.88	per cent.
2.	Empire Breaker, Baltimore Vein.		
	Old style crushers	11 96	"
	New style	8.03	"
3.	Empire Breaker—Hillman Vein.		
	Old style crushers	17.68	"
	New style	11.96	"
4.	Ashley No. 6 Breaker.		
	Baltimore Vein	11.56	"
	Ross	10.99	"
	Red ash	5.88	"
5.	Sugar Notch No. 10 Breaker.		
	Old style rolls	18.75	"
	New style	13.15	"
6.	Lance No. 11 Breaker.		
	Old style crusher, prepared rolls	$15\frac{90}{112}$	"
7.	Nottingham No. 15 Breaker.		
	Old style rolls	$12\frac{36}{112}$	"
8.	Reynolds No. 16 Breaker.		
	Old style prepared rolls	$17\frac{6}{112}$	"

This list might be carried still farther but the general average will be found to be close to 11 per cent. to 13 per cent., which by adding 4 per cent waste in screening makes 15 per cent. to 17 per cent. as the average waste for both operations, which is very close to Col. Brown's estimate of 15.27 per cent.

In comparing the proportion of sizes made at Bernice it must be remembered that the screen meshes are as follows:

Broken	over $2\frac{1}{4}$ in. & $2\frac{1}{2}$ in.;	
Egg	" 2 in.	through $2\frac{1}{4}$ in. & $2\frac{1}{2}$ in.;
Stove	" $1\frac{1}{4}$ in. & $1\frac{1}{2}$ in.	" 2 in.;
Nut	" $\frac{3}{4}$ in.	" $1\frac{1}{4}$ in. & $1\frac{1}{2}$ in.;
Pea	" $\frac{1}{2}$ in.	" $\frac{3}{4}$ in.;
Buckwheat and dirt		" $\frac{1}{2}$ in.

It should also be remembered that the demand for coal as large as broken, is quite limited, so that an effort is made to make as little even of this size as possible.

The average "run of mines," coal at Bernice, as determined by careful experiments, is as follows:

	Per cent.
Egg, and larger	55
Stove	8
Nut	3
Pea	12
Buckwheat and dirt	18
Slate and bone	4
	100.00

The average mine waste, including buckwheat coal, may therefore be set at 22 per cent.

During the year 1887 the total waste in the breaker, including, of course, mine waste, was $35\frac{1}{10}$ per cent., which leaves for the waste in preparation during an actual year's run, not during a short, indecisive test, only $17\frac{1}{10}$ per cent.

Allowing for the 4 per cent. of slate contained in the coal coming from the mines, which is picked out by hand during the process of preparation, and also for the usual 4 per cent. for waste in screening, we have a total of 8 per cent. to be deducted from $17\frac{1}{10}$, leaving $9\frac{1}{10}$ per cent. as the actual waste in breaking. The waste in screening is probably much more in this case, owing to the friable nature of the coal and the extra length of the screen, which is necessarily more or less crowded when screening 450 tons per day. Thus the waste at Bernice, subdivided, would stand:

	Per cent.
Waste in mining	18
Refuse (slate and bone)	4
Waste in breaking	$9\frac{1}{10}$
Waste in screening	4
Total	$35\frac{1}{10}$

No results of any very lengthy test as to the proportion of the various sizes which might be made under favorable circumstances of demand can be given, since "broken," and sometimes even "egg," are often in but slight demand, necessitating either a rebreaking of these sizes or lowering of the monkey teeth, thus diminishing the percentage of the larger sizes and correspondingly increasing that of the smaller sizes and of the waste.

The following shows the percentage of production during 1886 and 1887:

	1886.	1887.
	Per cent.	*Per cent.*
Broken	7.30	6.00
Egg	15.00	19.83
Stove	32.00	27.75
Nut	23.36	22.10
Pea	22.34	24.32
	100.00	100.00

The coals at Bernice commanding the best market and correspondingly the highest price are "stove" and "nut," then come "egg," "broken" and lastly "pea."

In 1886 a series of experiments were carried on at Drifton, Pa., at the works of Messrs. Coxe Bros. & Co.,* to determine the waste made when using Coxe's patent fluted rolls, which it was claimed made less waste with the ordinary anthracites than the usual steel-toothed rolls; but in none of the experiments with the Bernice coal did the actual breaking waste alone amount to less than 20 per cent., when breaking down

*For comparison the following is the proportion of size made by a large breaker with Lykens Valley coals, during one month:

	Per cent.
Broken	11.10
Egg	19.60
Stove	24.40
Nut	16.70
Pea	28.20
	100.00

from the larger sizes, and yet a one-eighth inch mesh was used to separate out the dirt, just one-quarter of the size used at Bernice when, in actual runs, the breaking waste is only 9 per cent.

On the plant at Bernice it has given entire satisfaction. Of course 35 per cent. of waste and about 24 per cent of merchantable coal made being "pea" sometimes brings complaint from the management, which is perfectly natural, and would be still so, even were these figures reduced one-half. But in general this may be considered a good result as at many collieries operating on similar coals, these figures are much higher. It is doubtful whether the crusher at Bernice would be suitable for a much harder coal, at least it has never been tried; but for Bernice coal, with its bituminous fracture making it easily split, it works admirably. Were a new plant to be erected, many very desirable changes would be effected whereby the cost of handling and probably the waste would be reduced. To introduce these changes in the present plant would necessitate a complete remodeling.

APPENDIX B.

A NEW FORM OF SCREEN, ESPECIALLY ADAPTED TO USE WITH SOFT COALS.

BY ARTHUR WINSLOW.

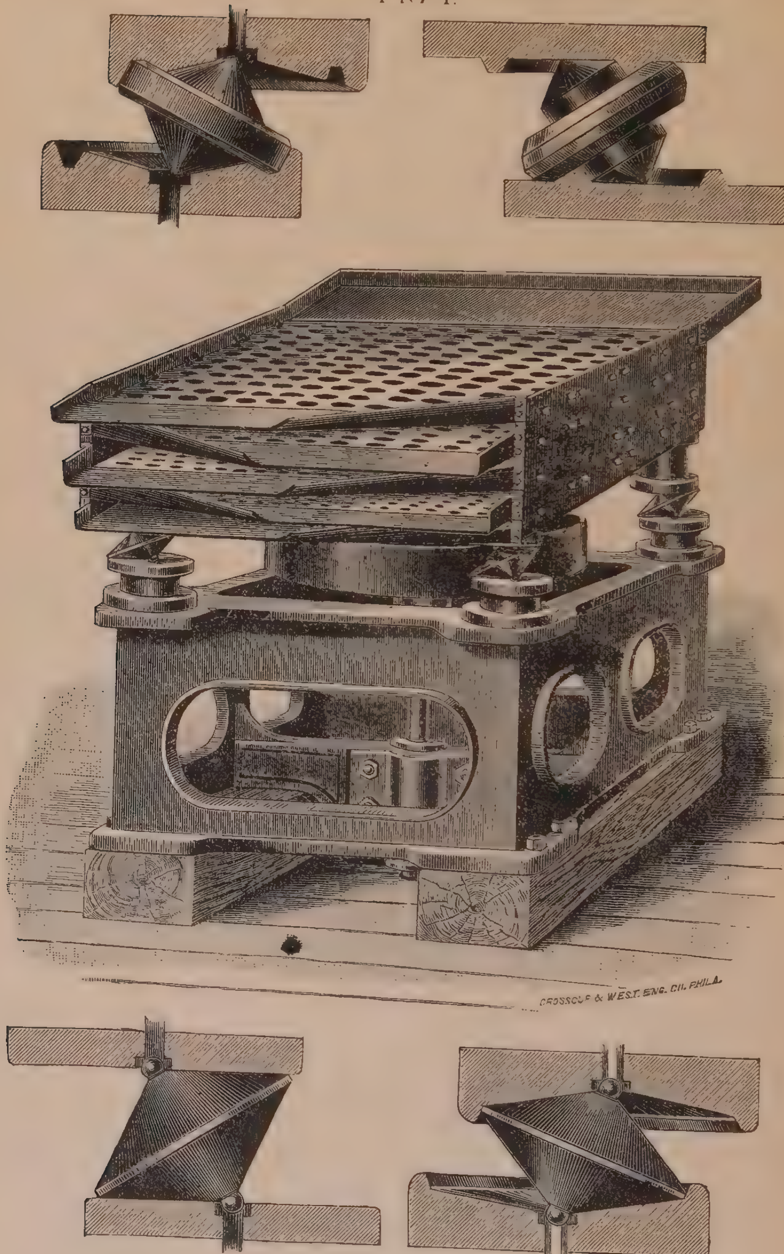
The preceding paper treats principally of a method of crushing the softer coals in preparing them for market. The Bernice crusher seems to meet the requirements admirably. Subsequent to this crushing, however, the coal has yet to be screened to the various market sizes. A screen especially adapted to soft coals is still a *desideratum.* One recently patented and now manufactured by Coxe Bros. & Co., of Drifton, Pennsylvania, is offered as an improvement over the older forms, and, as it has several features which recommend it for use with Arkansas coals, the accompanying illustrations are presented.(*)

Fig. 1, represents the smaller size of "gyrating screen" and details of the cones upon which the screen runs are also shown. The patented motion principle gives to the screen the motion that a moulder gives his sieve when sifting sand. The coal falls on the upper end and, as the sifting motion is given to the screen and the jackets are slightly inclined, the coal passes slowly down the screen; the largest sizes going off on top, the second on the next shelf, the third on the next and the fourth on the next, and the dust goes off on the bottom. The large wheel beneath the shelves is a fly wheel or counter weight, which is so balanced as to take up the centrifugal force of the screen. It is driven by a hemp rope, one single three-fourths inch rope giving all the power necessary.

Figures 2 and 3 represent respectively the front and the rear view of the double gyrating screen of the larger size, with a deep box. This double form of screen is a considerable im-

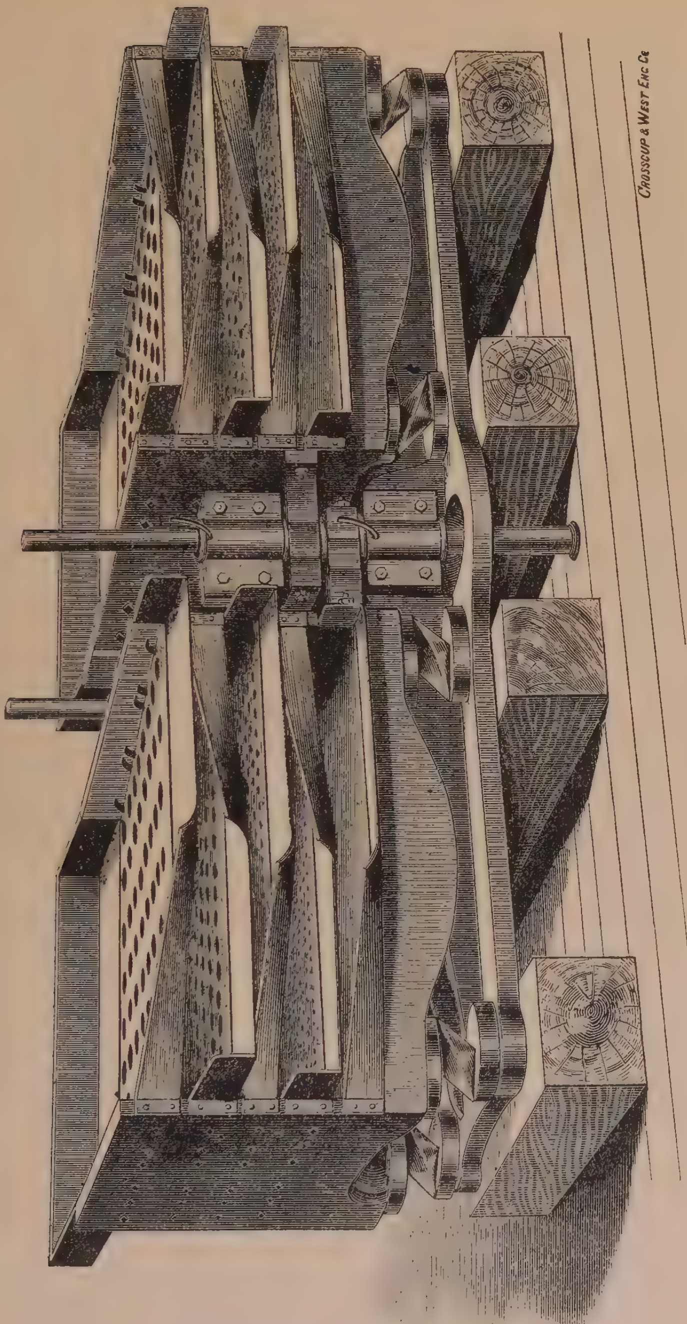
(*)From plates kindly furnished by Coxe Bros. & Co., Drifton, Pa.

FIG. 1.



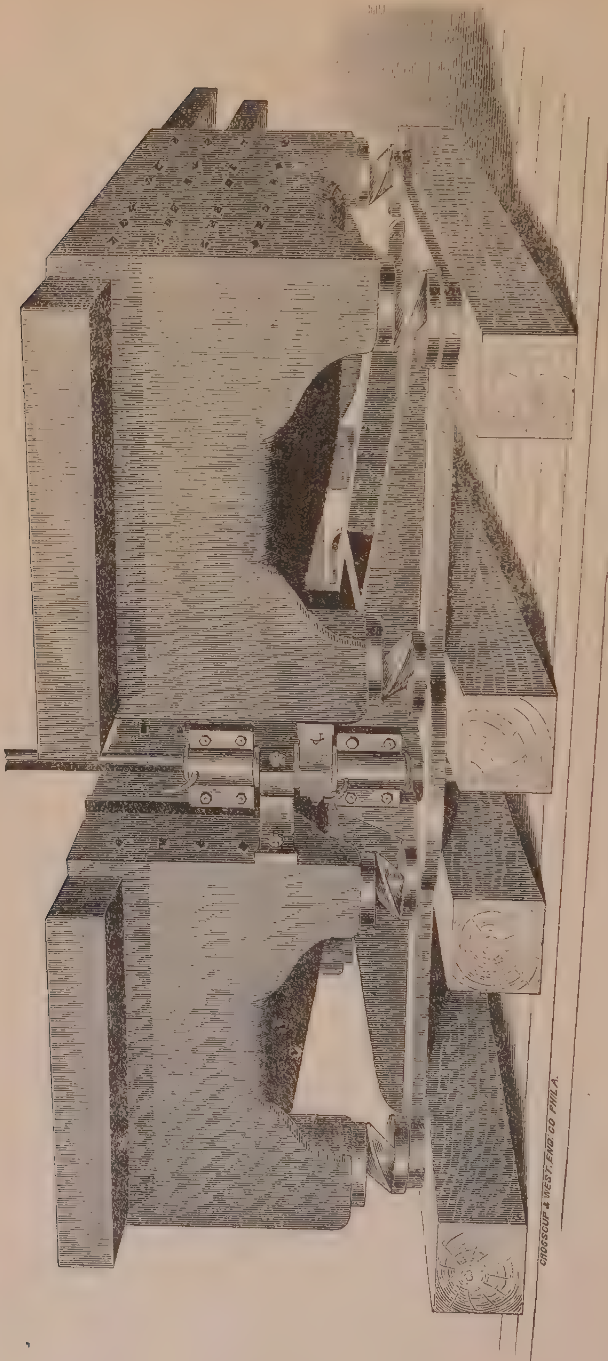
SINGLE GYRATING SCREEN.

FIG. 11.



DOUBLE GYRATING SCREEN, FRONT VIEW.

FIG. III



DOUBLE GYRATING SCREEN, BACK VIEW.

provement over the single form. The two screens are balanced one against the other, which does away with the necessity of having a heavy counterweight. The manufacturers claim that they can thus increase the capacity of the screen in the ratio of four to ten without increasing the cost of the screen in anything like that ratio.

A large number of these screens are used by Coxe Bros. & Co. at their collieries, and by other parties, all of which are giving very good satisfaction. The manufacturers claim that the machine is able to make a better separation than any they have ever seen. At present they are screening anthracite very successfully over round holes three thirty-seconds of an inch in diameter and through three-sixteenths, over three-sixteenths and through one fourth, etc., up to four and one-half inches. The screen is peculiarly adapted to soft and friable coals, as the pieces of coal do not tumble over each other, but pass very rapidly over the screen.

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